Optimisation de l'utilisation du personnel roulant

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Optimization of the Passenger Crew Utilization

Massachusetts Bay Commuter Railroad Company

MBCR

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[Summary]
In 2003, the MBTA called for tenders to contract out management of the Boston suburban train network to a private company. The MCBR was chosen to manage and operate the Boston commuter rail system for 5 years. As a large railroad transportation company, MBCR constantly strives for profitability while offering superior commuter rail services its customers. In this regard, the improvement of the crew management is one of the motivations of MBCR in order to find less costly and more responsive solutions to the network's operations. Designed to respond to this intention of optimizing the crew utilization, this report will aim on the development of a new train crew management system for the commuter rail service, and will also detail various analysis focused on the absenteeism, the vacation systems and the Extra Boards.

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[Résumé]
Au terme d'un appel d'offre lancé par le MBTA, la MBCR a remporté en juillet 2003 l'exploitation du réseau de trains de banlieue de Boston pour une durée de 5 ans. L'exploitation de ce réseau, précédemment opérée par AMTRACK, n'a jamais fait l'objet d'études d'optimisation des coûts d'exploitation et d'utilisation du personnel roulant. C'est dans cette optique d'optimisation que ce stage trouve sa source, et ce à travers différentes études interconnectées. L'étude principale concerne l'optimisation de l'utilisation du personnel roulant existant et se traduit par la production d'un nouvel habillage pour toutes les catégories de personnel roulant, c'est à dire l'élaboration de nouveaux services et de nouveaux roulements. Les études secondaires se traduisent par des analyses sur l'absentéisme, les vacances et enfin les listes supplémentaires.

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SUMMARY

INTRODUCTION

In 2003, for the first time in the history of the United States, the Massachusetts Bay Transportation Authority (MBTA) called for tenders to contract out management of the Boston suburban train network to a private company. The Massachusetts Bay Commuter Railroad Company (MCBR), which is 60%-owned by CONNEX North America, was chosen by the MBTA to manage and operate the Boston commuter rail system.

As a large railroad transportation company, MBCR constantly strives for profitability while offering superior commuter rail services to more than 140,000 daily customers in the Boston metropolitan area. In this regard, the improvement of the crew management is one of the motivations of MBCR in order to find less costly and more responsive solutions to the network's operations. Indeed, an effective utilization of the staff greatly improves a railroad transit operation's reactivity and service quality, keep costs down, and can improve both customers and employees satisfaction.

Designed to respond to this intention of optimizing the crew utilization, this report will aim on the development of a new train crew management system for the commuter rail service in order to improve crew efficiencies. This study will include the development of new runs for the passenger crew, part known as the crew scheduling, as well as the development of new rosters and new equipment cycles. After a complete analyze of the current train crew management system and the identification of all the related problems, we will explain in detail the process of the crew scheduling and rostering, from the various constraints arising from operational rules and work regulations to the costs forecasting and the impact on the human resources.

In addition to the crew scheduling project, this report will also detailed two other studies, one focused on the absenteeism, and the other on the Extra Boards that are the sets of employees that cover the vacant assignments. The absenteeism analysis will consist in giving an overview of the absenteeism over a long period of time in order to allow efficient and accurate forecasting. The Extra Board analysis will investigate the current absenteeism coverage capacity, try to determine the real needs of MBCR in terms of workforce for the Extra Board and eventually perform the costs forecasting. Those two studies will be the basis of the two main parts following the crew scheduling chapter.

This report can be considered in its totality both as an overview of the current network's situation, but also as a set of proposals aiming at answering to a global problematic of optimization. It will investigate new possibilities in different issues such as train crew management and absenteeism management. Every proposition presents itself with its background, its detailed description (for which the reader will likely refer to the annex report), the analysis of its consequences on the operations and the costs forecasting.

PART 1: CONTEXT, PROBLEMS & OBJECTIVES

This chapter will first introduce the Boston area and its mass transit system, with a particular effort in describing the commuter railroad network. After this part aimed at depicting the context of the study, we will focuse on the various problems in order to understand why MBCR is willing to improve the train crew efficiency. This will eventually lead us to detail the different objectives arising from this problematic.

I. Context of the Study: the Boston area and its mass transit system.

1. Quick facts about Boston.

Boston is the capital of Massachusetts and the biggest city in the state, with a population of 589,000 (*census year 2000*) and 2,850,000 in its greater metropolitan area (*source Veolia Environnement*).

Figure 1: Aerial view of Boston

Boston is one of the oldest cities in the United States and is associated with all the major liberal causes in American history: the revolution, independence, abolition of slavery and emancipation of women. Boston was the most influential city in New England, and, more importantly, the historic capital of the United States.

At the same time, Boston is a typical city that has been rejuvenated by becoming the country's No. 2 business center, after New York. It is also a port and major university city (Boston University, Harvard, MIT and Clark). As many as half a million of the 3 million people living in the metropolitan area are students.

2. About the "T": The Chronicle of the Boston Transit System.

While Boston is the birthplace of American liberty, it is also the birthplace of American mass transportation. The first public transportation services in Boston date back to the beginning of the 17th century and the ferry boats linking downtown Boston, which is located on a peninsula, to the mainland.

Since then, the network of services has grown steadily (the nation's first subway, the Green Line, under Boston Common between Park street and Boylston was inaugurated in 1897) and now comprises various modes of transport, including trams, trolley buses, boats, subways, trains and buses.

In the early 1960s, urban planners set up the Massachusetts Bay Transportation Authority (MBTA), a public body responsible for unifying, modernizing and operating the existing network in a bid to halt the expansion of automobile traffic. Today, the MBTA service

district extends over almost 2,700 km^2 and includes 175 cities and towns with a total of 2,600,000 inhabitants. (*source Veolia Environnement*)

The system contains a total of 186 routes including 4 Subways lines, 162 Bus and Trolley lines, 13 Commuter Rail lines and 4 Ferry lines. Approximately 792,600 one-way passenger trips are taken on the "T" every day. The ridership numbers below show the number of passengers boarding each of the lines on a typical weekday. Note that the total number of passengers boarding is greater than the total number of passenger trips, since many people transfer between lines to make a complete trip. The table also shows that the subway boardings represent more than 50% of the total boardings, with 30% for the bus and 12% for the rail.

Ridership by mode / line	Daily Boardings
Red Line	210,500
Green Line	204,800
Orange Line	154,400
Blue Line	55,600
Silver Line Washington Street	14,100
Mattapan Trolley	7,800
MBTA Bus	356,400
MBTA Trackless trolleybus	11,900
Contracted bus	4,400
Commuter Rail	143,100
Water Transportation	4,700
The RIDE (paratransit)	5,300
Total Passenger Boardings	**1,173,000**

Table 1: "T" Ridership by mode in 2004
Source: www.mbta.com

Figure 3: Map of the Subway lines
Source: MBTA

Figure 2: MBTA Logo

3. The Boston commuter railroad network.

In 2003, for the first time in the history of the United States, the MBTA called for tenders to contract out management of the Boston suburban train network to a private company. Previously the network had been operated by AMTRAK.

This was a remarkable initiative because it demonstrated the local authorities' determination to break free from Amtrak's grip in order to find less costly and more responsive solutions to their needs.

3.1. MBCR, a new company to operate the Boston railroad system.

The Massachusetts Bay Commuter Railroad Company (MCBR) is the result of a partnership among three leading transportation companies. It is 60%-owned by CONNEX North America, 20%-owned by the Canadian train manufacturer BOMBARDIER and 20%-owned by the Boston-based transportation firm ALTERNATE CONCEPT, INC. It was chosen by the MBTA to manage and operate the Boston commuter rail system, effective July 1st, 2003.

The contract between MBCR and the MBTA, which is worth $1 billion, runs for five years. It does not require any investment by the operator. Aside from network operation, it encompasses:

- maintenance of the infrastructure, stations and rolling stock;
- creation of a dedicated passenger service centre for the suburban network;
- development of training programs for staff;
- inspection of the equipment and the development of investment programs for network modernization;
- development of new management and payroll IT systems.

The mission of MBCR is to work in full cooperation with the MBTA to provide superior commuter rail services for the Boston metropolitan area. Its goal is to operate a safe and reliable service that exceeds expectations every day.

3.2. Key facts and figures about one of the largest suburban train network.

The MBCR commuter rail network has grown over the years because of infrastructure improvements, population growth and job creation in the region. Today it has 13 lines, 125 stations and almost 700 km of track served by 466 trains per day. This is the fifth largest network in the United States behind the three New York region networks (Long Island, Metro North and New Jersey) and the Chicago network.

3.2.1. Thirteen lines that connect Boston to its metropolitan area.

The Boston Commuter Rail network comprises two “independent” networks, known as Northside and Southside.

The North Side, which is the smallest one, has 5 lines heading to North Station, linking the north part of the greater metropolitan area to the north of the Boston Downtown peninsulia. The North Station is located on the green and orange subway lines, for a quick access to the business center and the financial district. Starting from North Station, those 5 lines, served by 187 trains every day, connect to 55 stations up to 80 Kilometers away from Boston.

The South Side has 8 lines heading to South Station, linking the south part of the greater metropolitan area to the south of the peninsulia, with a direct access to the financial district and the business center. South Station, which is part of the city's architectural heritage, has 13 platforms and connections to the red line, the silver line and the bus network. Starting from South Station, those 8 lines, served by 279 trains every day, connect to 68 stations up to 70 Kilometers away from Boston.

Figure 4: Map of the commuter rail lines – source MBTA

The transport system provides very good connections between the commuter rail lines and the subway lines (*see figures 3 and 4*). Actually, the red line connects with 4 stations from two different commuter lines as well as South Station. The orange line connects with 4 stations from 6 differents lines (including Back Bay station which is common to 5 South side lines), as well as North Station, so as the green line does. This allows for the rail commuters a quick transfer toward every parts of the city.

The tables below summarize the following information for each line of both North and South sides, which are going to be usefull for the next part of the study:

- the length of the line in kilometers;
- the average riding time of a trip between the two terminal stations;
- the departure time from the terminal station of the first inbound train;
- the departure time from North or South Stations for the last outbound train;
- the number of daily trains serving on the line.

North Side Lines	Line Length (Km)	Riding Time (min)	First Inbound	Last Outbound	Number of Trains
Rockport	56.8	70	5:05 AM	12:10 AM	26
Newburyport	44.3	65	5:27 AM	10:40 PM	38
Haverhill	52.6	65	5:31 AM	11:59 PM	46
Lowell	40.8	45	5:35 AM	11:59 PM	42
Fitchburg	79.2	85	5:45 AM	12:10 AM	35

Table 2: Northside lines characteristics in 2005 – source MBCR

South Side Lines	Line Length (Km)	Riding Time (min)	First Inbound	Last Outbound	Number of Trains
Attleboro	69.4	65	5:25 AM	11:59 PM	35
Stoughton	30.1	35	6:28 AM	11:00 PM	38
Framingham/Worcester	70.9	80	6:06 AM	11:25 PM	41
Needham	21.9	40	6:10 AM	10:30 PM	32
Franklin	49.3	60	5:15 AM	11:50 PM	37
Fairmount	14.6	20	6:00 AM	9:40 PM	40
Middleborough/Lakeville	57.0	55	5:25 AM	10:30 PM	24
Plymouth/Kingston	57.0	55	5:30 AM	10:40 PM	32

Table 3: Southside lines characteristics in 2005 – source MBCR

3.2.2. A significant daily ridership.

With a network extending up to 175 municipalities, the Commuter Railraod Company provides its service to more than 140,000 passengers each weekday. The main part of the ridership is using the trains on a daily basis for a job-related commute.

Based on the number of one-way passenger trips on page 7, we can estimate that the part of the "T" users riding a Commuter Rail train is 18%, which is a good result for a suburban train network.

Table 4: Ridership of the commuter rail lines in 2004

North Side Lines	Daily Boarding
Rockport	7,800
Newburyport	10,800
Haverhill	10,900
Lowell	11,100
Fitchburg	9,000

South Side Lines	Daily Boarding
Attleboro/Stoughton	28,100
Framingham/Worcester	18,800
Needham	9,200
Franklin	15,200
Fairmount	2,400
Middleborough/Lakeville	9,800
Plymouth/Kingston	10,000
Total Commuter Rail:	**143,100**

Source: www.mbta.com

Clearly, the ridership is more homogeneous on the North side, whereas the ridership distribution on the South side is more disparate, with some really cohesive lines and smaller ones like the Fairmount line (AKA the Readville shuttle).

3.2.3. More than 1700 employees dedicated to the good functioning of the network.

MBCR has 1,764 employees working to provide passenger superior commuter rail services (*source HR Department, 08/25/05*). We call passenger crew the employees working on board the trains. They represents less than a third of the total staff, with around 500 passenger engineers and passenger trainmen, including the conductors and the assistant conductors (or AC's). Therefore we can deduce that the engineering, maintenance, and all other departments represent a significant part of the total human resource of MBCR.

The passenger engineers are driving the trains, while the passenger trainmen are verifying the validity of the tickets (by paying a small additional charge, passengers can buy their tickets on board) but also help to look after the safety of passengers and manage the opening and closing of train doors. We will call Road Crew the team composed of one engineer and one conductor. On average, three MBCR agents are on board each train to assist passengers.

Figure 5: MBCR passenger crew

The exact figures on August 25th for the passenger crew resources are 151 passenger Engineers and 319 passenger Trainmen (*source Crew Dispatching Department*).

3.2.4. The rolling stock and the facilities.

MBCR operates a total of 56 locomotives, primarily including F40s, GP40s and a few GP9s all running with diesel. On the South side, the passenger travel in 213 cars, many of which have two levels, hauled by 33 locomotives. On the North side, the passenger travel in 122 cars, all of which are single level, hauled by 23 locomotives. All the cars are accessible for disabled passengers, and bicycles are welcome during off-peak hours. (*source MBCR*)

Figure 6: MBCR locomotive

MBCR handles the maintenance of all the network's equipment at a site comprising several workshops that are able to house entire trains for major overhauls, repairs, repainting and cleaning of cars and locomotives.

The trains are stocked overnight in various facilities usually located close to each of the terminal stations. The following tables detail the location and the capacity in terms of trains' storage of each yard and facility.

North Side Facilities	Storage capacity
BET (Boston Engine Terminal)	7
Rockport Facility	4
Newburyport Facility	4
Bradford Facility	4
Fitchburg Facility	4

South Side Facilities	Storage capacity
South Station + Southampton yard	10
Readville yard (day only)	*8*
East Junction Facility	4
Franklin Facility	3
Worcester Facility	4
Needham Heights Facility	3
Kingston Facility	4
Middleborough Facility	4

Table 5: Storage capacity of the MBCR facilities
Source: MBCR

II. A network with a heritage that limits profitability.

MBCR was chosen in July 2003 by the MBTA to manage and operate the Boston commuter rail system for five years, in a $1 billion worth contract. This network was previously operated by AMTRAK.

In its answer to the RFP (Request For Proposal), CONNEX built Crew Runs for engineers, conductors and assistant conductors of both South and North sides that have never been implemented. Those RFP crew runs were built with a management approach that would improve the productivity of the passenger crew and the cost efficiency of the network operations.

This chapter will describe in detail the different drawbacks of the current network's operations so that we will be able to identify where the potential savings are and what can be possibly done to improve the productivity and the cost efficiency.

1. Overview of the sides of the operations that could be improved.

One of the MBTA's motivation to call for tenders was to find less costly solutions for the network's operation. In fact the previous operator AMTRAK have never been using any optimization tools to find a cost-effective solution that responds to the passengers, the employees and the MBTA's needs. Today, as the RFP runs have never been implemented, MBCR is still operating the network using the previous Amtrak's runs and rosters. The current crew runs are therefore really old and the related costs are a really important amount that MBCR is willing to reduce.

This part is meant to give an overview of the different issues related to the utilization of the old runs and rosters and aims to quantify the global cost they generate. Note that all the following tables have been built using the results of the work on the crew scheduling project detailed in the next part of this report.

- ***High overtime level:*** whereas the conventional daily working time is 8 hours, most of the runs actually last a lot more. Reducing the overtime is a critical issue for MBCR as the extra hours are payed at 150% of the regular rate.

Road Crew	Average overtime per run	
	Southside	Northside
Weekdays Run	1:55	1:21
Saturday Run	1:54	1:39
Sunday Run	1:08	1:13
Weekly Scheduled Overtime	**516:50**	**289:35**

Table 6: Average amount of overtime per run and weekly total

This table demonstrates that the total weekly amount of scheduled overtime over the whole network is superior to 800 hours. This figure represents the overtime of only one of the Road Crew category, which means there are more than 800 hours of weekly overtime for engineers and for conductors. The overtime associated to the assistant conductors also needs to be taken into account, as well as the unscheduled overtime resulting from any delays or problems encountered on daily service operations

The table below shows the weekly cost of the overtime for each category of employee, based on the new rates effective July 1st 2005. The overtime hourly rates are equal to $44.85 for the engineers, $37.74 for the conductors and $32.48 for the AC's (*source Payroll Department*).

	Weekly cost of overtime	
	Southside	**Northside**
Engineers	$ 23,180	$ 12,810
Conductors	$ 19,505	$ 10,780
Assistant Conductors	$ 8,200	$ 5,605
Total Cost of Overtime	**$ 50,885**	**$ 29,195**

Table 7: Weekly cost of overtime

The total weekly cost of scheduled overtime for the whole network is superior to $80,000, which represents an extra cost of more than **$6,500,000** per year. We therefore understand that reducing the overtime is critical to MBCR as this is where the main potential savings can come from.

- ***Reduced productivity-efficiency:*** it results from two different types of runs.

The first type of non efficient run is the run shorter than 8 hours. In fact, given the labor union agreement, each working day has to be paid 8 hours, even though the run lasts less than 8 hours. This leads to pay some employees some hours during which they are actually not working.

Road Crew	**Southside**		**Northside**	
	# runs < 8 Hours	Average length	# runs < 8 Hours	Average length
Weekdays Run	2 (4%)	6:27	2 (6%)	7:08
Saturday Run	2 (10%)	7:05	2 (12%)	7:12
Sunday Run	5 (26%)	6:48	3 (20%)	7:29
Weekly total non productive hours		**23:20**		**11:50**

Table 8: Overview of the runs comprising non productive hours

From those figures, we can estimate the total cost that MBCR is paying for hours that are not actually worked. Summing the cost relative to the engineers and the cost relative to the conductors of both sides, the total cost for non productive hours exceeds **$100,000** a year. It does not take into account the cost for AC's non productive hours, which is

estimated at **$45,000** per year. The regular hourly rates used for this cost forecasting are equal to $29.90 for the engineers, $25.16 for the conductors and $21.65 for the AC's (*source Payroll Department*).

The second type of non effective run is a run comprising an extended break between two trains (typically between 1 and 2 hours), during which the employee is being paid at full rate. This phenomenon is hard to quantify, but can be reduced by modifying the trains' arrangement within the runs, or by introducing a release between the trains when the interval is long enough.

- ***Hours of service (HOS):*** this term signifies that the employee is being given a rest day paid 8 hours because his previous runs actually exceeds the legal working time, consequence of a possible delay or problem during his service.

Three types of runs can lead to HOS:

- Straight runs that are too close to 12 hours in spread: given the Unions agreements, a run with a spread longer than 12 hours is supposed to include a release of 4 hours minimum. If the run happens to exceed 12 hours because of any type of delay, the employee is being given an 8 hours pay rest day.
- Split runs that are too close to 16 hours in spread: if the run happens to exceed 16 hours because of any type of delay, the employee is being given a rest paid day. Indeed this doesn't allow the employee to have 8 hours of rest between two services, which is the minimum legal time.
- Split runs with a release too close to 4 hours: given the Union agreements, a run with a spread longer than 12 hours is supposed to include a release of 4 hours minimum. If the first part of the service experiences any delay so that the release would become shorter than 4 hours, the employee wouldn't be able to do the second part of his service and go home early with the pay of his assignment.

The table below summarizes the average number of weekly HOS for passenger engineers and trainmen, calculated over 30 weeks from December 2004 to July 2005 (*source Absenteeism analysis – see annex S23, S24, N22 and N23*). The cost calculation is based on an 8 hours pay day, assuming that half of the trainmen's HOS are associated with the conductors and the other half is due to the AC's. The regular hourly rates used for this calculation are mentioned page 14.

	Average number of HOS per week	
	Southside	**Northside**
Engineer	4.5	1.4
Trainmen	5.1	3.1
Annual Cost	**$ 105,630**	**$ 47,600**

Table 9: Average number of HOS per week and annual total cost

This table highlights that the estimated cost of Hours of Service exceeds **$150,000** per year. It could be reduced by having runs less close to the legal working time limits.

- ***No standardization of the various empty moves:*** some differences can be noticed for the current runs regarding the time allocated to each empty moves (or passenger extra – PX) between the stations and the facilities, or also regarding the time allocated to walk between the facility and the station. Although those differences are usually small (< 5 minutes), it is important to have a standardization of the time of those moves.

- ***Insufficient number of employees for the Extra Board:*** the number of employees in the Extra Boards (for both sides and each category of employees) is not sufficient enough to cover all the daily absenteeism. The consequence is that Extra Board employees can be called to make some 6th and 7th days, which are both paid at 150% of the full rate. In the case the Extra Board employees can't cover all the 6th and 7th days, regular employees can be called too and will also be paid at 150% of the full rate.

The average weekly costs relative to the 6th and 7th days are summarized in the table below. Those costs have been calculated as the average of the weekly grand totals of the 6th and 7th days' costs over 31 weeks from the 1st week of January 2005 to the 1st week of August 2005 included (*source Payroll Department*).

	Weekly cost of 6th and 7th days	
	Southside	**Northside**
Engineer	$ 4,500	$ 3,090
Trainmen	$ 7,835	$ 5,185
Total weekly cost	**$ 12,335**	**$ 8,275**

Table 10: Weekly grand total of 6th and 7th days

The cost induced by the insufficiency of Extra Board employees is significant as it represents around $640,000 per year for the Southside and $430,000 per year for the Northside, that is to say more than **$1,000,000** per year for the whole network. Having a more consequent Extra Board could help to significantly reduce this annual cost (the days would still have to be paid, but at a normal rate).

- ***Inadequate utilization of the Assistant Conductors:*** the number of Assistant Conductors in each train depends on the number of passengers in the train, and on the number of cars open to service (*see page 43-44*). Currently, given the last passenger counts (*April 2005 for peak hours trains and September 2004 for all other trains*) and the number of cars open, many trains are overstaffed, while a few are understaffed and thus are not compliant with the labor agreement and/or the MBTA agreement.

The table below summarizes the number of trains overstaffed and understaffed with AC's for both South and North Sides on the weekday trains (*see annex S14 and N13*).

	Overstaffing		Understaffing	
Southside	148	**53%**	5	2%
Northside	53	**28%**	0	0%

Table 11: Overview of the current AC's staffing

This table proves that the number of overstaffed train is really important as more than one weekday train out of two is overstaffed on the Southside, and almost one out of three on the Northside. In comparison the understaffing is almost negligible but is nevertheless problematic as it goes against the agreements.

- ***Poor absenteeism overview:*** the absenteeism problem, besides the fact that the Extra Board is to short, resides in a lack of a global overview. There is a weekly overview but no follow-up to have an annual overview which would allow a better knowledge of the absences' level and therefore allow accurate and efficient forecasting.

- ***Historical vacation system:*** the number of days of vacation is based on the seniority, and all the vacation weeks have to be taken within a 6 month spread. This is problematic for MBCR as a great number of employees are on vacation at the same time, therefore leading to a lack of crew and an increase of the operation costs.

2. The means of action to overcome those problems.

High overtime level, low productivity efficiency, and hours of service issues can each be attenuated by reworking the runs and the rosters for the Road Crew. This process is called crew scheduling and crew rostering, and will be the main topic of the next part. This basically consists in efficiently use the existing crew to staff trains, in compliance to various constraints from the labor union contracts to the federal regulations, but also operational rules and worker's preferences.

We can also rework the runs and rosters for the AC's, so as to reduce the overstaffing and to be in compliance with the labor agreement and the MBTA agreement for the trains that are currently understaffed.

We might also have to rework the equipment cycles, also called vehicle schedules, that haven't been modified for years and may be now be a little obsolete.

Regarding the insufficiency in terms of human resource for the Extra Boards, MBCR may want to hire some new employees. A cross analysis between the absenteeism study, the vacation study and the crew scheduling study can be the opportunity to estimate the real needs and then the number of required employees.

3. Importance of an effective crew management in the railroad.

An effective management of rail crew is a core capability all railroads require. The trend of industry deregulation and restructuring is increasing the requirement for all aspects of a railroad's operation to be more and more competitive and efficient. A railroad must have the crew management systems and processes in place that allow to:

- efficiently use crew to staff trains;
- plan crew operations quickly and efficiently;
- minimize crew related train disruptions;
- provide a fair and equitable work environment for crew;
- monitor and manage crew fatigue and safety;
- respond quickly to train and crew changes;
- efficiently manage rail crew.

Crew scheduling and crew rostering are two of the major tasks involved in managing large transportation networks. These important tasks are concerned with the development of duty schedules for crew to cover a given timetable in a transportation system.

Crew scheduling and rostering are complex problems. They are often large, with many staff to accommodate. Moreover, practical instances of crew scheduling and rostering applications involve many hard constraints arising from operational rules and different work regulations that need to be taken into account. Also soft constraints linked to workers' preferences in accordance with social and family life are involved.

The main objective of the crew scheduling and rostering is to minimize the overall roster cost accrued from using the available crew while providing the required number of crew for each train trip in the schedule. This improvement of cost efficiency can be achieved while utilizing human resources more effectively, in a way that however satisfies the employees' personal preferences.

To sum up, an effective utilization of the staff greatly improves a railroad transit operation's reactivity and service quality, keep costs down, and can improve both customers and employees satisfaction. We can therefore understand the will of MBCR to break free of Amtrak's historic runs and rosters and to explore new possibilities for its crew scheduling.

III. Definition of the objectives.

The main objectives of this internship will naturally come from all that have been said previously, in order to try to respond efficiently to MBCR's expectation to provide superior commuter rail services at optimized cost, in a way that will satisfy the customers as well as the employees and the MBTA.

- ***Crew scheduling and crew rostering project:***

As described previously, the crew scheduling and the crew rostering are two of the major tasks involved in a cost-effective railroad crew management. Therefore this project is the primary objective of this internship and will be the main topic of the next part of this report. This will include:

- Standardization of the different moves;
- Building new Road Crew runs for Northside and Southside, using 2003 RFP crew runs proposal as a starting point, for weekdays, Saturdays and Sundays, in compliance with all the constraints;
- Building new rosters for Engineers and Conductors of Northside and Southside, based on the new runs' proposal;
- Reworking the equipment cycles to be compliant with the new Road Crew runs' proposal;
- Building new runs for Assistant Conductors of Northside and Southside in compliance with the agreements based on the most recent passenger counts, for weekdays, Saturdays and Sundays;
- Building new rosters for Assistant Conductors of Northside and Southside, based on the new runs' proposal;
- Costs forecasting, estimating the potential savings.

- ***Absenteeism and vacation analysis:***

The absenteeism analysis will consist in building a working sheet that will provide an overview of the absenteeism over a long period of time (typically 1 year), in a format that will be efficient and accurate. This should obviously allow separate and accurate analysis of each type of absence, for each day of the week.

The vacation analysis will consist in investigating two different scenarios including the possibility of spreading the vacations' weeks over one year, instead of 6 months currently.

- ***Extra Board analysis:***

Synthesizing the two previous objectives' results, we will investigate the real needs of MBCR in terms of workforce for the Extra Board. This will be done for the current network situation as well as for the hypothetical situation, should the new runs and rosters be implemented. A cost forecasting will be performed for each case.

PART 2: CREW SCHEDULING AND CREW ROSTERING

We saw in the first part of this report that one of the main issues regarding the optimization of the utilization of the passenger crew was the crew scheduling and rostering. Obviously a suitable crew scheduling allows utilizing the manpower resources more effectively and improves cost efficiency. This part will describe in detail the whole process of building new runs and rosters for the MBCR passenger crew, from the main principles of the crew scheduling to the very results and the potential savings that can be expected from the proposals.

I. Generalities on Crew Scheduling and Crew Rostering.

1. The process of the production of services.

The following diagram describes the global aspects of the production of services process, identifying every parameter that have to be taken into account. We have to note that most of those parameters are actually constraints that cannot be modified (Boxes in red), whereas the boxes in blue are parameters that can eventually be modified.

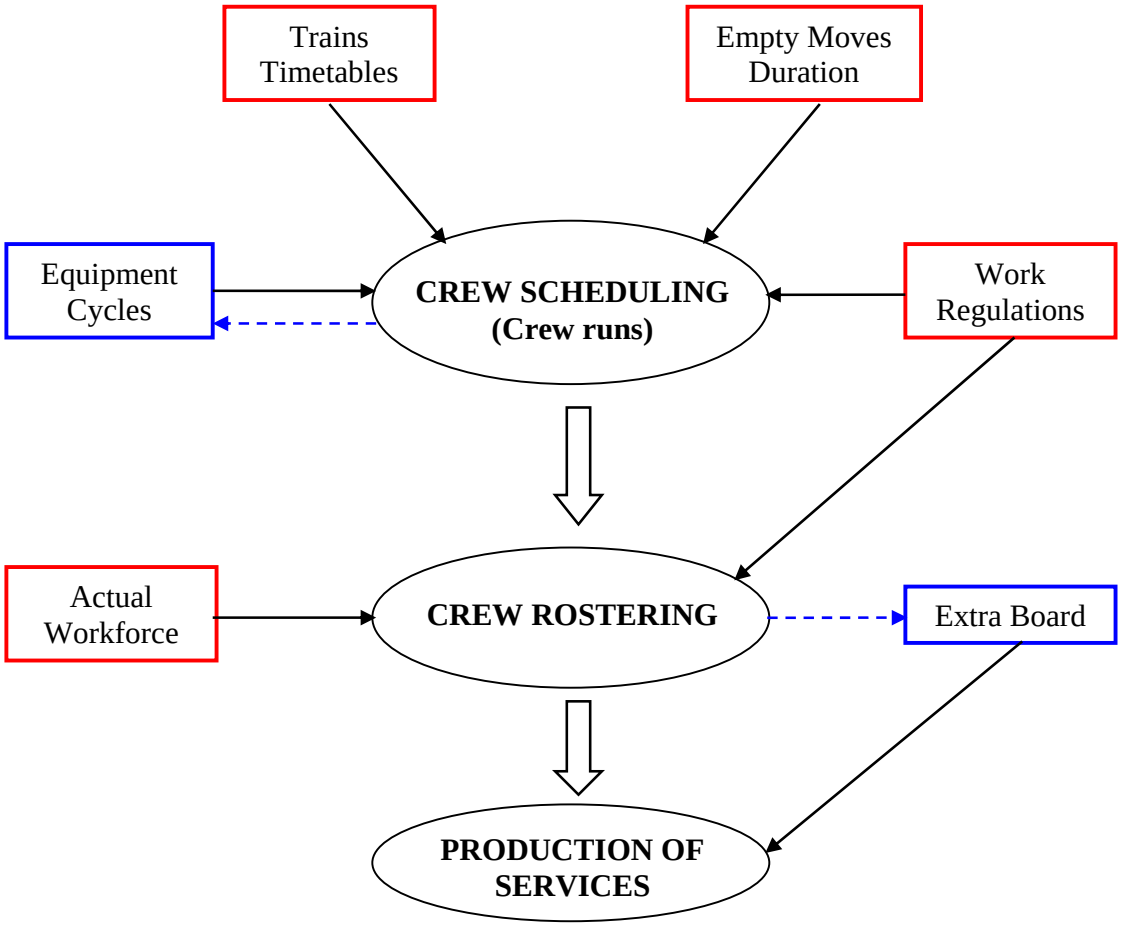

Figure 7: Diagram of the production of services process

This diagram gives a global overview of the general process of the MBCR crew scheduling and rostering that will have to be followed. We have to emphasize the fact that we are starting from an already operating network, with existing timetables, existing equipment cycles et cetera. If we had to start from the very beginning, the regular process would be to start building the equipment cycles (also known as vehicle schedules) and the timetables given the lines' book of specifications, and from then build the crew runs and rosters. In our specific case, the equipment cycles can be modified in consequence of new crew schedules.

This diagram highlights that there are 3 major constraints for the crew scheduling, which are the trains timetables, the empty moves duration, and the work regulations (including Federal laws and Unions agreements).

Regarding the crew rostering, the major constraint will be the work regulations (and implied "quality of life" standards), as well as the actual workforce as we will have to utilize the existing resources to cover the runs.

2. The three major aspects of a crew scheduling project.

Before going in the details of the constraints and of the methodology, it seems important to have in mind the three major aspects of a Crew Scheduling project.

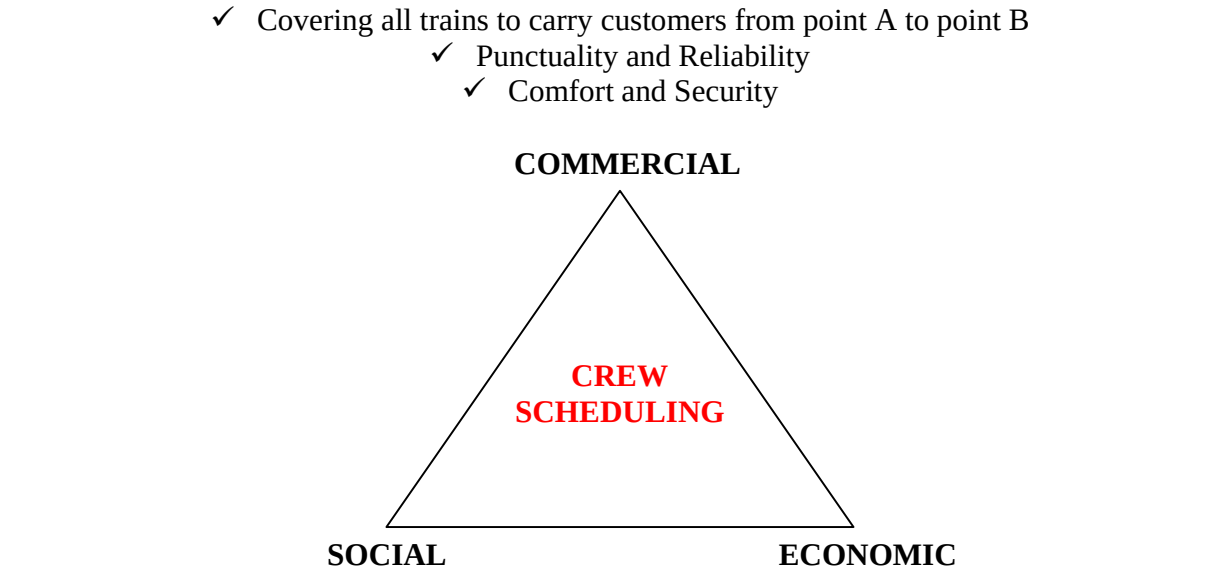

Figure 8: Diagram of the crew scheduling aspects

Therefore, solving a Crew Scheduling problem will suppose to find a balance between those three aspects in order to find a solution that will satisfy the customers (commercial aspect), the employees (social aspect) and the employer (economic aspect).

II. Road Crew scheduling: new runs and rosters for engineers and conductors.

We will start the study of the crew scheduling project with the Road Crew scheduling (we remind that we call Road Crew the association of one passenger engineer and one passenger conductor). Precisely the Road Crew runs are the most important runs as they are the ones that have to cover all the trains with no exceptions. In this chapter we will first describe the functioning of the network's operations, the various specific constraints, the methodology of building the runs and the rosters and finally the results and the potential savings that ensue.

1. How the network operates.

Before beginning the description of the specific constraints linked to the Road Crew, it seems important to have a global overview of how passenger operations are run on the network.

A train crew (AKA Road Crew) is composed of one passenger engineer, who is driving the train, and one passenger conductor, who verifies the validity of the tickets but also helps to look after the safety of passengers and manages the opening and closing of train doors. One or more additional conductors (the AC's) can assist the passenger conductor in his duty. One passenger engineer's run is strictly identical to his associated conductor's run, meaning we will only have to build one set of runs which will be common to both of them.

In addition to the passenger services (or passenger trains), the Road Crew may have to cover some empty moves (AKA "Passenger Extra" or "PX") between the different facilities and stations. This is especially true for the early and late runs. Indeed the Road Crew will have to move each locomotive from the facility where it was stored during the night to the station where it will make its first passenger service. Similarly, the Road Crew will have to bring the equipment to its assigned facility when the vehicle "duty" (e.g. all the passenger services than one vehicle has to do as described in the equipment cycle) is done. Whereas a Road Crew starting its duty in one location must absolutely finish its duty at the exact same location, the equipment may ends at another facility depending on the equipement cycle.

In addition to the empty moves between the facilities and the stations at the beginning and at the end of each vehicle runs, Road Crews may have to bring trainsets to the yard during off-peak hours. In fact every single equipment need to be taken to the yard for maintenance, cleaning, and especially fueling as all the locomotives run with Diesel.

There are two yards on the South side, Southampton and Readville, and one on the Northside, Boston Engine Terminal (BET), each of those comprising special tracks for maintenance, cleaning and fueling. The moves to the yards all start from North or South Station (and vice-versa the moves from the yards all head towards those two stations). They can also be operated by the so-called "House Engineers". Operating those empty moves between the station and the yard is the only duty of the House Engineer, so that most of Road Crews can focus on operating the passenger trains.

The last thing that must be mentionned is the fact that a Road Crew can go from the yard to the station in an equipment operated by another Road Crew. This is called a deadhead move (whereas in the usual transportation language "deadhead" means any kind of empty move, deadheading for MBCR will only refer to a crew moving in a train operated by another crew) and is usefull to bring a crew to the station at a precise time when no other equipment than the one already assigned the other crew is leaving the yard.

All those specifications will have to be taken into account during the development of the runs. Except the empty moves, the runs of the Road Crew will consist in operating the passenger services, which usually go as a pair, meaning one outbound followed by one inbound. Also a run can be straight or split, with a release between the two parts of the run. A release can only takes place in North or South Station or in one of the three yards.

2. The road crew scheduling, a highly constrained problem.

The crew scheduling optimization problem is to assign crew to scheduled trains over a time period, so that the crew cost is minimum and the schedule honors many operational and contractual requirements. This problem is highly constrained due to various labor union agreements and federal labor laws, but also operational rules and workers' preferences. This chapter will describe in details the various constraints that will have to be taken into account for the development of every single run.

2.1. Five main constraints.

- ***Covering all trains:***

The addition of all the runs must cover all the trains with no exception (passenger services as well as PX moves). This can sound like a commonplace but this is however the biggest constraint.

- ***Runs start and end at the same facilities:***

As said previously every run must start and end at the same facility. Here again no exception is allowed. The minimum number of runs starting from each facility depends on the capacity of the facility (*see table 5*).

- ***Compliance with the Federal Labor laws:***

Congress enacted the Hours of Service Act in 1907 to enhance railroad safety by limiting the number of hours that railroad engineers and other railroad employees can work. Locomotive engineers and other transportation employees can work a maximum of 12 consecutive hours followed by at least 8 hours off duty.

- ***Compliance with the Union Labor agreement:***

In addition to the Federal Labor laws, the Unions agreements determine the other limitation in terms of working time. The maximum spread of one run cannot exceed 16 hours, followed by at least 8 hours off duty. Any run whose spread exceeds 12 hours must comprise at least a 4 hours release. The minimum release time is assessed at 1:10 hours. A release starts 20 minutes after the last train arrival and ends 30 minutes before the next train departure, which is the time estimated in the agreement to assist the passengers in going in or out and to prepare the train.

- ***Compliance with the empty moves duration:***

Every PX move is a fully part of the run and therefore the time to make this move has to be taken into account for the determination of the sign up (SU) and sign out (SO) times. The difference between SO and SU gives the working time of the run. If a crew is deadheading an empty move, it will sign up 10 minutes later than the regular SU time if the train is leaving the facility, and sign out 10 minutes earlier than the regular SO time if the train is coming back to the facility.

The five constraints above are non negotiable and therefore determine the basis to which we will have to subjugate during the development of the runs.

2.2. Finding the balance between the three aspects.

As described previously, solving a crew scheduling problem suppose to find a balance between the social, economic and commercial aspects in order to find a solution that will satisfy the customers, the employees and the employer. The following points will therefore detail the constraints that result from the choices that have been made by several MBCR's departments of operation.

- ***Balance between economic and social aspects:***

We need to find a balance between the productivity and the well-being of the employees. The runs have to be built in a way that allows each employee to have a sufficient break time to eat, have a cup of coffee or go to the restrooms for instance. We came to the conclusion that each run must comprise one break at North or South Station of at least 30 minutes. The employees' well-being will also have a non negligible impact on the commercial aspect, as they will be in better conditions to provide customers a superior service.

Another balance has to be found between the costs' minimization and the company's traditions. Regarding the release, even though the minimum agreed time is 1:10 hour, the Amtrak's runs used not to have any release shorter than 1:40 hour. We came to the conclusion that it would be better to maintain this usage so as not to get the Unions' disapproval on this matter.

Finally, we need to find a balance between the crew management and the federal and unions labor regulations. In reality we wish that the reworked runs would prevent, or at least reduce, the Hours of Service. It has been decided that a 20 minutes security gap should be introduced to preventively absorb any potential delay that could lead to a HOS.

Practically this means:

- ✓ No straight run longer than 11:40 hours;
- ✓ No release shorter than 4:20 hours if the spread exceeds 12 hours;
- ✓ No split run with a spread longer than 15:40 hours.

- ***Balance between economic and commercial aspects:***

One of the biggest issues in the development of the runs concerns the way how the arrangement of the trains can be made. In fact the Unions agreements don't specify any legal time to respect between two trains. This interval must be determined as a balance between the economic point of view and the commercial point of view.

On one hand, the pursuit of productivity tends to shorten this time, whereas the commercial aspirations take advantage of a longer interval. Effectively, if it happens to be a delay and that the interval between the two trains is too short, there will be a repercussion on the next train's departure which will eventually be delayed. This goes against the commitment of MBCR to provide its customers a punctual and reliable service. Similarly, having too shorts intervals may urge the engineers to drive too fast, decreasing both the comfort and the security of the ride.

But operation issues are also involved in the determination of this minimum interval. The main one is the brake test which is performed for every train before it leaves its originating station. For instance, before any train departs from South or North Station, the engineer must apply and release the brakes, and a car inspector at the other end of the train must insure that the brakes applied and released on the rear end of the train. Similarly, when the train gets to its final destination and is then scheduled to return to Boston, the engineer must again apply and release the brakes, and a Conductor or Assistant Conductor stationed at the rear of the train must insure that the brakes have applied and released on the rear end of the train. Other constraints that require some interval of time include the need for the Conductor to walk through every coach of the train to make sure that all of the passengers have exited the train, and time for the engineer and/or the conductor to contact the dispatcher to receive any messages or special instructions for the train.

As a balance between productivity and reliability, we came to the following conclusion:

- ✓ Minimum interval of 15 minutes during peak hours;
- ✓ Minimum interval of 12 minutes during off-peak hours.

When this is the same equipment, meaning that the crew doesn't have to go to another track to operate another train but remains in the same train, the minimum interval is determined by the timetables and the equipment cycles and is currently 9 minutes. This hasn't been modified.

Those various constraints are more arbitrary than the five previously mentioned, nevertheless the runs will have to be in complete compliance with them to be found workable and acceptable by the Unions.

2.3. Three additional constraints.

There are three more constraints that need to be mentioned, however those are not as restricting as the ones above as we can modify the equipment cycles in consequence of the choices we make for the runs.

- ***Runs in compliance with the Yards capacity:***

This constraint is specific to the South side. There are 33 equipments that all need to go to on of the two yards during the off-peak hours. Among those 33 trains, at least 7 need to go to the yard of Readville and the rest to the yard of Southampton. Given the current House Engineer staff, at least 5 out of the 7 release trips to Readville must be operated by the Road Crew. Each of those empty moves (way-in and way-back) last 1:30 hour in average, which create important constraints as it represents more than 3 hours of PX moves within the run. While building the runs, we may need to send equipments to Readville that previously had their release in Southampton (and vice-versa), which leads to modify the equipment cycle in consequence.

- ***Runs in compliance with the House Engineers staff:***

We must ensure that the new runs provide approximately the same amount of "Road Crew operated" empty moves between the Stations and the Yards (or vice-versa) than currently so as to be sure that the current House Engineer staff will still be able to operate all the others empty moves. Actually it is interesting in terms of cost efficiency to let the House Engineers take care of those operations, while giving a release to the Road Crew at North or South Station. This basically represents a gain of working time of one hour. However it is not in our interest to build runs that would require more House Engineers to operate those empty moves, so the idea is basically to have as many "Road Crew operated" empty moves than currently. We must always have this constraint in mind while building the runs, however we can still make some little modifications to the equipment cycles if we encounter any problem.

- ***Runs start and end at the same location:***

This constraint is close to the one mentioned previously, however it only concerns the runs starting from Southampton for the Southside or BET for the Northside. As contrary to the runs starting from the other facilities where trains going out in the morning and coming back in the night are well established (depending mainly on the timetables), trainsets going to the yards or coming back from the yards only depend on the equipment cycles. After building the runs in terms of trains' arrangement, we need to figure out a trainset that will bring the crew to the station at the beginning of the run and vice-versa an equipment that will bring the crew back to the yard at the end of the run. This may lead to some conflicts with the equipment cycles when no equipment is supposed to make the expected move at the expected moment. This can be solved by making very small modifications to the equipment cycles.

3. The methodological approach of building the Road Crew runs.

The first step was to determine what the field of action was. We came to the conclusion that the crew scheduling project would focus on the passenger crew only and that it was not necessary to modify the other services (House Engineers, Terminal Switchers, Wash Crew, Fuel Crew, etc.).

It was decided that the project would start with the work on the weekday runs for the Southside Road Crew so as to assimilate all the problems, constraints and specifications. This was kind of a training that would allow me to be more independent for the further steps of the work, as many people were involved to help me learn fast. This step, besides the comprehension of the problems and constraints, was also the opportunity to build some effective printout format and documents for schedules and rosters that would be used all along the project.

After this step, the process was a logical one consisting in reworking the weekend runs then the roster for the Southside; then the same work was performed on the Northside (weekday runs then weekend runs then rosters). Eventually the same process would start again for the Assistant Conductors of South and North sides.

We are going to focus on the details of the methodology for the work on the Southside, all the further work basically following the same process:

- Meeting and discussion with persons from different department of operations: « Director of Manpower Utilization », « Assistant Manager of Crew Utilization », « Senior Trainmaster », « Manager of Transportation », « Manager of Operations Planning ». Iterative exchange of information with all the persons above to identify the constraints and the problems, learn the functioning of the network.
- Study of the existing runs: empty moves duration, current intervals, usual SU and SO times, House Engineers moves, et cetera. This important step gives a first idea of what must be done and how it can be done.

- Using 2003 RFP runs as a starting point, creation of effective excel working sheets for the runs description with a printout format (*see annex S4 and N3*). This document includes for each run: description of the trains' arrangement (with for each train its departure and arrival time) including every PX or deadhead moves, name of the facility where the run starts and ends, SU and SO times, working time, spread time, overtime and release time.
- Investigating the RFP crew runs feasibility: identification of the problems (e.g. identification of every thing that do not comply with the constraints), verifying that all the trains are covered.
- Building by hand new weekday runs using 2003 RFP runs as a starting point that comply with all the constraints. Working in parallel on the equipment cycle to make it workable with the new runs.
- 1-Verification of the workability of the new runs by the different departments of operations. 2- Modifications that reflect the comments received. Succession of steps 1 and 2 until complete validation of the runs.
- Building by hand new runs for Saturdays and Sundays. There are no RFP crew runs for the weekend, so the process basically consists in building the current weekend runs on the excel document and then modify them to find a better solution. Working in parallel on the equipment cycles to make it workable with the new runs.
- 1-Verification of the workability of the new weekend runs by the different department of operations. 2- Modifications that reflect the comments received. Succession of steps 1 and 2 until complete validation of the runs.
- Creation of effective excel working sheet to build the rosters for Engineers and Conductors using the new weekday and weekend runs and perform the cost calculation at the same time. Validation of the roster by the Crew Dispatching department.
- Performing the costs analysis.

4. Results of the Road Crew scheduling project.

4.1. New road crew runs.

✓ *Generalities on the run's construction:*

In order to be in compliance with the facilities capacity, the number of runs starting from each facility and the number of runs ending in each facility must be at least equal to their capacity detailed on table 5.

For the estimation of the SU and SO times, the empty moves duration detailed in annex S3 for the Southside and N2 for the Northside will be used. They are calculated as the average of the time allocated for the same moves in the current runs. From now the SU time of each run is calculated as the first run's train departure time minus the empty move

duration, according to the run's starting location. Similarly the addition of the last run's train arrival time and the empty move duration will give the SO time.

Ultimately, all the trains have to be covered by the runs in compliance with all the constraints detailed previously.

✓ ***The RFP crew runs:***

As said previously, those documents built by CONNEX in 2003 as an answer for the call for tenders will serve as a starting point of this work. Those documents include a complete set of crew runs and a complete set of equipment cycles for Southside and Northside. They were built with a management approach that would create the opportunity to either provide the existing service with fewer resources or provide more service for the same level of crewing effort.

The governing principles of the approach to managing these important service assets were the following (*source 2003 MBCR Transportation Plan, section 9.2 page 10*):

- Accurate scheduling and forecasting;
- Improvements in the productivity of both the crews and the trainsets;
- Compliance with assignments, contract requirement and customer needs.

✓ ***Saturday and Sunday runs:***

As detailed in the methodology, the weekend's runs must satisfy to the same criterions than the weekday's runs, the main difference relying in the fact that there were no RFP crew runs to start from.

The Saturday's runs and the Sunday's runs will be built independently as the number of trains to cover may vary between those two days.

Finally, it was decided that the run type (straight or split) had to be identical to the current one, in order to avoid a possible Union's disapproval on that matter. This means that if none of the runs of one set has a release, the proposed set must comprises only straight runs. On the other hand if some runs are currently split, we can build runs with a release.

4.1.1. New Road Crew runs for the Southside.

➢ ***Weekday's runs:***

The Southside weekday's runs will have to cover every of the 279 daily passenger trains as well as one empty train for equipment's protection purpose.

RFP feasibility investigation:

The set of RFP crew runs (*see annex S4*) comprises 46 runs, against 48 currently, with a potential economic saving of 6.8% (*source 2003 MBCR Transportation Plan, section 9.2*

page 11). After a cross-study of every run with the different constraints to see if they match them, the conclusion was the following (*see annex S5*):

- 26 runs were found workable (e.g. 55% of the runs);
- Among the 20 problematic runs:
  - 7 runs were not suitable in terms of trains interval;
  - 6 runs were not compliant with the 20 minutes security gap;
  - 5 runs were not compliant with the working regulations;
  - 4 runs did not provide a 30 minutes break at South Station.

We can notice that the sum of the problems exceeds 19 as some runs have more than one mismatching with the constraints. Moreover other problems eventually occurred: succession of two outbound trains, different starting and ending locations, one train not covered. We don't take into account the errors regarding the SU and SO times estimation as they are mostly not significant.

Starting from those results, the runs were modified by hand step by step until finding out a workable solution. Numerous initially workable runs had to be modified too. The final proposed set of crew runs for passenger engineers and conductors comprises 47 runs, including 9 runs that remain identical to the RFP (*see annex S6*). All those 47 runs were found workable and compliant with all the constraints.

Road Crew	**Weekday Southside runs overview**		
	Current	**Proposal**	**Variation**
Number of runs	**48**	**47**	**-1**
Spread *< 8 hours*	*2*	*0*	*-2*
[8-10] hours	*7*	*14*	*7*
[10-12] hours	*19*	*12+2*	*-5*
[12-15] hours	*14*	*16*	*2*
> 15 hours	*6*	*3*	*-3*
Average spread	**11:59**	**11:42**	**-2.5%**
Total regular	384:00	376:00	-2%
Total overtime	92:14	70:38	**-23.5%**
Total release	99:32	104:07	+4.5%

Table 12: Overview of the Southside weekday's runs characteristics

The table above summarizes the main figures regarding the two sets of runs and their comparison. We can first notice that the average run's spread is shorter for the proposal, and that the spread distribution is more efficient. (The figure 12+2 in the proposal column means that among the runs with a spread comprises between 10 and 12 hours, 12 are straight and 2 are split.)

But the main observation we can make is that the amount of overtime is reduced by almost 25%. For the current set, the average overtime per run is 1:55 whereas it goes down to 1:30 for the proposal. We remember that reducing the overtime was one of the main objectives of this crew scheduling project in order to reduce the costs.

➢ ***Weekend's runs:***

The proposed Saturday's and Sunday's runs were built using the current weekend's runs as a starting point. The Saturday's set of crew runs (*see annex S7*) has to cover 102 trains (plus two PX trains) and the Sunday's one (*see annex S8*) has to cover 74 trains (plus four PX trains). The governing principle of the reorganization of the trains' arrangement was basically to reduce either the number of runs or the amount of overtime.

Road Crew		Saturday Southside runs overview		
		Current	Proposal	Variation
Number of runs		**19**	**19**	**-**
Spread	*< 8 hours*	*2*	*0*	*-2*
	[8-10] hours	*4*	*9*	*5*
	[10-12] hours	*13*	*10*	*-3*
Average spread		**9:54**	**9:48**	**-1%**
Total regular		152:00	152:00	-
Total overtime		36:13	34:24	**-5%**

Table 13: Overview of the Southside Saturday's runs characteristics

Road Crew		Sunday Southside runs overview		
		Current	Proposal	Variation
Number of runs		**17**	**16**	**-1**
Spread	*< 8 hours*	*5*	*2*	*-3*
	[8-10] hours	*7*	*8*	*1*
	[10-12] hours	*5*	*6*	*1*
Average spread		**9:08**	**9:22**	**+2.5%**
Total regular		136:00	128:00	-6%
Total overtime		19:27	21:52	+12.5%

Table 14: Overview of the Southside Sunday's runs characteristics

The tables show that the restructuring of the Saturday runs result in a reduction of 5% of the overtime and that the number of runs to cover all the Sunday trains decreases by one without a significant increase of overtime.

4.1.2. New Road Crew runs for the Northside.

➢ ***Weekday's runs:***

The Northside weekday's runs will have to cover every of the 187 daily passenger trains as well as the 9 PX trains necessary to compensate the low capacity of the facilities (For example 5 trains are supposed to leave Bradford before the first outbound train from North Station arrives, but as the Bradford facility's storage capacity is only 4 trains one equipment has to be brought from BET).

RFP feasibility investigation:

The set of Northside RFP crew runs (*see annex N3*) comprises 33 runs, against 36 currently, with a potential saving of 5.1% (*source 2003 MBCR Transportation Plan, section 9 page 11*). After a cross-study of every run with the different constraints to see if they match them, the conclusion was the following (*see annex N4*):

- 23 runs were found workable (e.g. 70% of the runs);
- Among the 10 problematic runs:
  - 5 runs were not suitable in terms of trains interval;
  - 2 runs were not compliant with the 20 minutes security gap;
  - 3 runs did not provide a 30 minutes break at North Station.

Those three kinds of problems actually concerned only nine out of the ten problematic runs, the last one being non compliant with the Union labor agreement. Moreover three passenger trains and one PX trains were not covered by the set of crew runs. We don't take into account the errors regarding the SU and SO times estimation as they are mostly not significant.

Starting from those results, the runs were modified step by step until finding out a workable solution. Initially workable runs had to be modified too. The final proposed set of crew runs for passenger engineers and conductors comprises 34 runs (*see annex N5*). All those 34 runs were found workable and compliant with all the constraints.

Road Crew	Weekday Northside runs overview		
	Current	Proposal	Variation
Number of runs	**36**	**34**	**-2**
Spread *< 8 hours*	*2*	*1*	*-1*
[8-10] hours	*14*	*13*	*-1*
[10-12] hours	*9*	*9*	-
[12-15] hours	*10*	*10*	-
> 15 hours	*1*	*1*	-
Average spread	**10:50**	**11:04**	**+2%**
Total regular	288:00	272:00	-5.5%
Total overtime	48:28	43:47	**-10%**
Total release	53:28	60:51	+14%

Table 15: Overview of the Northside weekday's runs characteristics

The table above summarizes the main figures regarding the two sets of runs and their comparison. We can notice that the average run's spread for the proposal is longer than currently. This is especially due to an increase of the total release time (+14%). On the other hand the amount of overtime is reduced by 10%, which more than compensate the increase of the release time.

But the biggest improvement between the current set of runs and the proposed one is the fact that all the trains are covered with two less runs, which creates the opportunity to

provide the existing service with fewer resources. Therefore the productivity of the employees significantly increases.

We can add that 19 out of the 23 initially workable runs remain identical to the RFP, so we can say that the proposal reflects the managing approach of CONNEX.

- ***Weekend's runs:***

The Saturday's set of crew runs (*see annex N6*) has to cover 68 trains (plus four PX trains) and the Sunday's one (*see annex N7*) has to cover 66 trains (plus four PX trains). The main figures resulting from the restructuring are summarized in the tables below.

Road Crew	Saturday Northside runs overview		
	Current	Proposal	Variation
Number of runs	**15**	**16**	**+1**
Spread *< 8 hours*	*2*	*3*	*1*
[8-10] hours	*6*	*10*	*4*
[10-12] hours	*6*	*2*	*-4*
[12-15] hours	*1*	*1*	-
Average spread	**9:58**	**9:20**	**-6.5%**
Total regular	120:00	128:00	+7%
Total overtime	24:49	16:49	**-32%**
Total release	4:40	4:40	-

Table 16: Overview of the Northside Saturday's runs characteristics

Road Crew	Sunday Northside runs overview		
	Current	Proposal	Variation
Number of runs	**15**	**15**	**-**
Spread *< 8 hours*	*3*	*3*	-
[8-10] hours	*8*	*8*	-
[10-12] hours	*4*	*4*	-
Average spread	**9:13**	**9:13**	**-**
Total regular	120:00	120:00	-
Total overtime	18:27	18:27	-

Table 17: Overview of the Northside Sunday's runs characteristics

The approach of the restructuring for the Northside weekend's runs was a little different than the one for the Southside. In fact the runs were already pretty efficient and it was apparently not possible to find an alternative proposition that would provide more service with fewer resources (at least while reworking the runs by hand and mind). This is why no modifications were done on the Sunday's runs.

For the Saturday's runs, given the current number of extra assignments (*please refer to the "Rosters" upcoming paragraph for the explanation of the reasoning*), we came to the conclusion that one more run was profitable. This leads to a reduction of the overtime of

8 hours, almost the third of the total amount, which more than compensates the 8 extra regular hours in terms of costs. Such a restructuring is therefore doubly profitable.

4.2. New equipment cycles.

Although the crew scheduling problem is usually solved after the vehicle schedules have been designed, we were compelled to make some modifications on the equipment cycles depending on the new crew runs.

Nevertheless we don't want the modifications to have a significant impact on the network operations, so we must try to minimize them. Moreover modifications in the equipment cycles can only happen between two strictly equivalent trainsets, e.g. between two trains with the same number of coaches and seats.

4.2.1. New equipment cycles for the Southside.

Two reasons led to do some modifications on the weekday's equipment cycle. The first one was the need to send 7 trains to Readville for release. The possibilities were not really numerous as it is highly constraining in terms of working time, so we had to adjust the equipment cycle in consequence. That is, we had to make the trains going to Readville on the crew runs actually going to Readville on the equipment cycle.

The second reason was the fact that we must ensure that the new runs provide approximately the same amount of "road crew operated" empty moves between South Station and Southampton yard (or vice-versa) than currently so as to be sure that the current House Engineers staff will still be able to operate all the others empty moves. This sometimes led to make some small modifications.

The proposed weekday's equipment cycle is available in annex S1. The proposed weekend's equipment cycles are available in annex S2.

4.2.2. New equipment cycle for the Northside.

After building the runs in terms of trains' arrangement, we need to find a trainset that will bring the crew to the North Station at the beginning of the run and vice-versa a trainset that will bring the crew back to the BET yard at the end of the run. This may lead to some conflicts with the equipment cycles when no equipment is supposed to make the expected move at the expected moment. This can be solved by making very small modifications to the equipment cycles.

The other reason that can lead to modify the equipment cycle is the same than the second reason mentioned in the Southside's paragraph.

The proposed weekday's equipment cycle is available in annex N1. No modifications were done on the weekend's equipment cycles.

4.3. New rosters.

After solving the crew scheduling problem, the resulting duties must be assigned to individual crew members. This process is called crew rostering. The MBCR's rosters consist in weekly assignments, which are basically a combination of weekdays and weekends runs.

4.3.1. Constraints of the crew rostering.

Just like the crew scheduling, the crew rostering process must comply with various federal labor laws and Unions agreement. First of all, each weekly assignment is a combination of 5 consecutive weekdays and/or weekends runs, followed by two consecutive days off. Secondly, the minimum off duty time between two consecutive runs is 8 hours. This means the difference between the SO time of the "day n" run and the SU time of the "day n+1" run must be at least equal to 8 hours.

As we wish to build employee's friendly rosters, we will also try to reduce the number of different locations within a weekly assignment. Ideally, a weekly assignment consists in 5 consecutive runs all starting from the exact same location.

In addition to the passenger crew weekly assignments, the MBCR's rosters also comprises the weekly assignments for the other crew (House Engineers, Terminal Switchers, Fuel Crew, …), the Extra assignments which are the non-assigned Saturday's and Sunday's runs, and the description of the guaranteed Extra Board with the relief day assigned to each employee of this list. We have to insist on the fact that all the other crew assignments will not be modified.

An important aspect of the rostering process was to try to reduce the number of Extra assignments, as they are often covered as 6^{th} or 7^{th} days and thus cost a lot of money. Therefore we will try to insert the weekend's extra assignments into regular weekly assignments, using the existing staff. We have to understand that we can only reduce the extra assignments 5 by 5. Indeed, suppressing 5 extra assignments allows creating one new regular weekly assignment. This is the reason why we may be urged to increase the number of weekend runs so that the total number of extra assignments will be a multiple of 5, like it was done for the Northside for instance.

4.3.2. New road crew rosters for the Southside.

SOUTHSIDE	*Weekday runs*	*Saturday runs*	*Sunday runs*	Regular assignments	Extra assignments	Other assignments	Other extra assignments	Extra Board
Engineers	*48*	*19*	*17*	54	6	15	4	10
Conductors	*48*	*19*	*17*	54	6	10	2	9

Table 18: Overview of the current Southside rosters characteristics

The main thing than can be explained from this table is that the number of regular and extra assignments is a function of the number of runs. In fact as described previously a regular assignment is a succession of 5 consecutive runs.

The total number of runs to assign is (48*5 + 19 + 17) = 276 runs. If we divide this number by 5, this give us 55 regular assignments and 1 run left which becomes an extra assignment. We have to remember that only weekend's runs can be extra assignments. In this case, the roster was built in a way that provides 54 regular assignments and 6 extra assignments.

Like it was said previously, we will have to use the existing staff to cover all the new proposed runs. We can thus build a proposed roster consisting in a maximum of 54 regular assignments for the passenger engineers and conductors. The table below summarizes the number of runs that will have to be inserted in the proposed roster.

SOUTHSIDE	*Weekday runs*	*Saturday runs*	*Sunday runs*	Total Runs
Engineers	*47*	*19*	*16*	**270**
Conductors	*47*	*19*	*16*	**270**

Table 19: Southside proposed runs' number summary

If we divide 270 by 5, we obtain 54 regular assignments and no extra assignment left. This is therefore the way the new rosters will be built: 54 regular assignments which all have to comply with the constraints previously detailed. *The rosters for passenger engineers and conductors are available in annex S10 and S11.*

SOUTHSIDE	Regular assignments	Extra assignments	Other assignments	Other extra assignments	Extra Board
Engineers	54	0	15	4	10
Conductors	54	0	10	2	9

Table 20: Overview of the Southside proposed rosters characteristics

4.3.3. New road crew rosters for the Northside.

NORTHSIDE	*Weekday runs*	*Saturday runs*	*Sunday runs*	Regular assignments	Extra assignments	Other assignments	Other extra assignments	Extra Board
Engineers	*36*	*15*	*15*	41	5	10	1	9
Conductors	*36*	*15*	*15*	41	4	8	0	8

Table 21: Overview of the current Northside rosters characteristics

We can notice that the number of extra assignments differs from the engineers to the conductors. The reason is that on of the Saturday's extra assignment is actually assigned to one of the Herder Crew employee (the conductors' equivalent of the House Engineer). This table shows that we will be able to build a proposed roster with a maximum of 41 regular assignments for the passenger engineers and conductors.

NORTHSIDE	*Weekday runs*	*Saturday runs*	*Sunday runs*	Total Runs
Engineers	*34*	*16*	*15*	**201**
Conductors	*34*	*16*	*15*	**201**

Table 22: Northside proposed runs' number summary

If we divide 201 by 5, we obtain 40 regular assignments and one extra assignment left. This is therefore the way the new roster will be build: 40 regular assignments which all have to comply with the constraints previously detailed and one weekend's run which become an extra assignment. *The rosters for passenger engineers and conductors are available in annex N9 and N10.*

NORTHSIDE	Regular assignments	Extra assignments	Other assignments	Other extra assignments	Extra Board
Engineers	40	1	10	1	10
Conductors	40	0	8	0	9

Table 23: Overview of the Northside proposed rosters characteristics

A few observations can be made. First of all the conductor's extra assignment is still assigned the one of the Herder employee, so there are no extra assignments for the passenger conductors. But the main difference between the current roster and the proposed roster relies in the fact that there is one regular assignment less. The employee who was previously assigned to the "41st assignment" now belongs to the extra board. The proposal thus provides 10 employees for the engineer's extra board and 9 employees to the conductor's extra board.

4.4. The costs analysis.

The rosters allow calculating the total weekly cost of the network operations but also the individual weekly wages for each employee (*see annex S12, S13, N11 and N12*). The following paragraphs will focus on the costs forecasting and will identify the potential savings that could result from the implementation of the proposed rosters.

4.4.1. About the wages calculation. *(source Payroll Department)*

The first thing which needs to be underline is the fact that each working day is paid at least 8 hours, even for the shorter runs. Every minutes after 8 hours is paid at 150% of the regular rate. The release time is paid at 50% of this rate.

One particularity concerns the runs with a release and an effective working time shorter than 8 hours. In this case, the release is not paid in its totality but as a function of the actual working time. In fact the double of the difference between 8 hours and the actual working time is being subtracted to the release time for its payment.

*Paid release = Actual release – 2 * (8 hours – Actual working time)*

Let's take the example of a run with a 13 hours spread, including 7 hours of work and 6 hours of release. The payment for this run will include the payment of 8 hours of work at full rate and the payment of 4 hours of release at 50% of the rate.

Finally a $5.00 per day Certification Allowance is included for all regular passenger engineer's assignment.

Engineers	
regular rate	$29.90
overtime rate	$44.85
release rate	$14.95

Conductors	
regular rate	$25.16
overtime rate	$37.74
release rate	$12.58

Table 24: Hourly rates for the passenger engineers and conductors, effective July 1st 2005
Source: Payroll Department

The rates described above are valid for the employees with at least five years of seniority. An employee will be paid 75% of the rate during his first year, 80% of the rate during his second year, and so on up to 100% starting from its sixth year.

4.4.2. Couple of assumptions for the costs calculation.

For all the following costs calculation, we make the assumption that all the employees have a five years seniority and are therefore getting paid at the full rate (this assumption is valid as a great majority of the employees have actually been working here for more than 5 years). Also we assume that all extra assignments are paid like regular days. For all the further costs calculation, the "regular assignments" costs forecasting will actually comprise the costs of the regular assignments plus the cost of the extra assignments.

Regarding the Extra Board cost calculation, we will proceed as followed: each employee on the extra board's list is paid 5 days at the average daily pay, and then the average weekly cost of 6th and 7th days is added (*see table 10*). We assume that the 6th and 7th days will be only covered by the extra board employees, whereas it is actually more about 80% covered by them and 20% covered by the regular employees. This assumption allows taking the cost of those days in its totality.

4.4.3. Significant costs' reduction for the Southside operations.

- **Regular assignments' costs:**

ENGINEERS SOUTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation
Average Daily Pay	**$ 355**	**$ 340**	**-4%**
Total regular	$ 67,400	$ 65,935	-2%
Part of regular	*69.2%*	*72.2%*	
Total release	$ 7,270	$ 7,560	+4%
Part of release	*7.4%*	*8.2%*	
Total overtime	$ 23,180	$ 18,260	-21%
Part of overtime	*23.5%*	*19.7%*	
Total Engineers	**$ 97,850**	**$ 91,755**	**-6.2%**

Table 25: Cost forecasting for the Southside engineers' regular assignments

CONDUCTORS SOUTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation
Average Daily Pay	**$ 294**	**$ 282**	**-4%**
Total regular	$ 55,555	$ 54,345	-2%
Part of regular	*68.4%*	*71.4%*	
Total release	$ 6,120	$ 6,360	4%
Part of release	*7.5%*	*8.4%*	
Total overtime	$ 19,505	$ 15,365	-21%
Part of overtime	*24.0%*	*20.2%*	
Total Engineers	**$ 81,180**	**$ 76,070**	**-6.3%**

Table 26: Cost forecasting for the Southside conductors' regular assignments

The total costs of the passenger operations for the Southside decrease by more than 6% for the engineers and the conductors. This diminution is mainly due to the reduction of the overtime by over 21%, which allows substantial savings. The part of the overtime in the total wages' costs goes from almost 24% to less than 20%.

The other interesting information is the fact the average pay for the Engineers and the Conductors only decreases by 4%, whereas the total cost decreases by more than 6%. This can be explained by the fact that the same crewing effort provides more services (disappearance of the extra assignments). The improvement of the productivity is therefore at the origin of this difference.

- ***Extra Board's costs:***

ENGINEERS SOUTH EXTRA BOARD COST	Average daily pay	Five Days Cost	Total Five Days	6th and 7th cost	Total Cost
Current (10)	$ 355	$ 1,775	$17,750	$4,500	**$22,250**
Proposal (10)	$ 340	$ 1,700	$17,000	$4,500	**$21,500**

Table 27: Cost forecasting for the Southside engineers' Extra Board

CONDUCTORS SOUTH EXTRA BOARD COST	Average daily pay	Five Days Cost	Total Five Days	6th and 7th cost	Total Cost
Current (9)	$ 294	$ 1,470	$13,230	$3,130	**$16,360**
Proposal (9)	$ 282	$ 1,410	$12,690	$3,130	**$15,820**

Table 28: Cost forecasting for the Southside conductors' Extra Board

Note that the cost of the 6th and 7th days for the conductors is proportionally established at 40% of the total cost for the trainmen.

➢ ***Overall cost of the roster:***

The following table details the global cost of the rosters, including the other types of crew and the extra boards, as well as the potential savings resulting from the implementation of those new runs and rosters.

TOTAL COSTS SOUTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation	Weekly savings	Annual savings
Total Passenger Engineers	$ 97,850	$ 91,755	-6.2%	$ 6,095	$ 316,940
Total Other Crew	$ 26,860	$ 26,860	-	-	-
Total Extra Board	$ 22,250	$ 21,500	-3.4%	$ 750	$ 39,000
Total Roster Southside Engineers	**$ 146,960**	**$ 140,115**	**-4.7%**	**$ 6,845**	**$ 355,940**
Total Conductors	$ 81,180	$ 76,070	-6.3%	$ 5,110	$ 265,720
Total Other Crew	$ 16,145	$ 16,145	-	-	-
Total Extra Board	$ 16,360	$ 15,820	-3.3%	$ 540	$ 28,080
Total Roster Southside Conductors	**$ 113,685**	**$ 108,035**	**-5.0%**	**$ 5,650**	**$ 293,800**
Total Southside	**$ 260,645**	**$ 248,150**	**-4.8%**	**$ 12,495**	**$649,740**

Table 29: Total Southside cost forecasting

From those figures we can see that the potential saving of implementing the proposed runs and rosters for the Road Crew on the Southside can reach **$650,000** per year. This represents a diminution of 4.7% of the cost for the engineers' operations and 5% of the cost for the conductors' operations.

4.4.4. Important potential savings expected on the Northside.

➢ ***Regular assignments' costs:***

ENGINEERS NORTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation
Average Daily Pay	**$ 325**	**$ 322**	**-1%**
Total regular	$ 51,280	$ 49,085	-4%
Part of regular	*75.2%*	*75.9%*	
Total release	$ 4,065	$ 4,145	2%
Part of release	*6.0%*	*6.4%*	
Total overtime	$ 12,810	$ 11,400	-11%
Part of overtime	*18.8%*	*17.6%*	
Total Engineers	**$ 68,155**	**$ 64,630**	**-5.2%**

Table 30: Cost forecasting for the Northside engineers' regular assignments

CONDUCTORS NORTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation
Average Daily Pay	**$ 269**	**$ 267**	**-1%**
Total regular	$ 42,070	$ 40,255	-4%
Part of regular	*74.9%*	*75.5%*	
Total release	$ 3,420	$ 3,490	2%
Part of release	*6.1%*	*6.5%*	
Total overtime	$ 10,670	$ 9,590	-10%
Part of overtime	*19.0%*	*18.0%*	
Total Engineers	**$ 56,160**	**$ 53,335**	**-5.0%**

Table 31: Cost forecasting for the Northside conductors' regular assignments

The total costs of the passenger operations for the Northside decrease by over 5% for the engineers and the conductors. This decreasing is mainly due to the reduction of the overtime by more than 10%, which allows substantial savings. We can notice that the diminution of the cost for the Northside is less important than the one for the Southside.

The most interesting thing for the Northside is the fact the average pay for the Engineers and the Conductors only decreases by 1%, whereas the total cost decreases by 5%. This can be explained by the improvement of the productivity, and is doubly profitable. Obviously this is profitable for MBCR who will be able to make substantial savings, but this is also good for the employees who will not be paid less. This is an important point to underline that can be crucial during the negotiations with the Unions.

Finally it is interesting to notice that, in average, an employee is currently being paid 8.5% less in the Northside than in the Southside. This difference is mainly due to the fact that there is more overtime in the Southside (24% of the costs in the South against 19% of the costs in the North). In the case of the proposal, this difference goes down to 5.3% because the reduction of overtime in more significant on the Southside than on the Northside.

- ***Extra Board's costs:***

Regarding the costs of the Extra Boards for the Northside, we will assume that the proposal cost of the 6th and 7th days will decrease by the amount of 5 average days paid at 150%, which will correspond to the capacity of work of the new employee in Extra Board. Basically it is equivalent to pay those five days at regular rate instead of paying them at overtime rate. The cost of 6th and 7th days for the conductors is determined proportionally at 50% of the trainmen cost.

ENGINEERS NORTH EXTRA BOARD COST	Average daily pay	Five Days Cost	Total Five Days	6th and 7th cost	Total Cost
Current (9)	$ 325	$ 1,625	$ 14,625	$ 3,090	**$ 17,715**
Proposal (10)	$ 322	$ 1,610	$ 16,100	$ 910	**$ 17,010**

Table 32: Cost forecasting for the Northside engineers' Extra Board

CONDUCTORS NORTH EXTRA BOARD COST	Average daily pay	Five Days Cost	Total Five Days	6th and 7th cost	Total Cost
Current (8)	$ 269	$ 1,345	$ 10,760	$ 2,590	**$ 13,350**
Proposal (9)	$ 267	$ 1,335	$ 12,015	$ 760	**$ 12,775**

Table 33: Cost forecasting for the Northside conductors' Extra Board

- ***Overall cost of the roster:***

TOTAL COSTS NORTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation	Weekly savings	Annual savings
Total Passenger Engineers	$ 68,155	$ 64,630	-5%	$ 3,525	$ 183,300
Total Other Crew	$ 20,145	$ 20,145	-	-	-
Total Extra Board	$ 17,715	$ 17,010	-4%	$ 705	$ 36,660
Total Roster Northside Engineers	**$ 106,015**	**$ 101,785**	**-4%**	**$ 4,230**	**$ 219,960**
Total Conductors	$ 56,160	$ 53,335	-5%	$ 2,825	$ 146,900
Total Other Crew	$ 12,515	$ 12,515	-	-	-
Total Extra Board	$ 13,355	$ 12,775	-4.3%	$ 580	$ 30,160
Total Roster Northside Conductors	**$ 82,030**	**$ 78,625**	**-4.2%**	**$ 3,405**	**$ 177,060**
Total Northside	**$ 188,045**	**$ 180,410**	**-4.1%**	**$ 7,635**	**$397,020**

Table 34: Total Northside cost forecasting

From those figures we can see that the potential savings of implementing the new runs and rosters for the Road Crew on the Southside amount almost to **$400,000** per year. This represents a diminution of approximately 4% of the cost for the engineers' and conductors' operations. We have to underline that an important part of those savings (more than $65,000 a year) comes from the reduction of the cost for the 6th and 7th days.

4.4.5. Conclusion.

If we consider the whole network, the potential savings linked to the implementation of new rosters for the Road Crew are superior to **$1,000,000** per year.

ESTIMATED ANNUAL SAVINGS SUMMARY	Southside	Northside	Total
Total Engineers	**$ 356,000**	**$ 220,000**	**$ 576,000**
Total Conductors	**$ 294,000**	**$ 177,000**	**$ 471,000**
Total Road Crew	**$ 650,000**	**$ 397,000**	**$ 1,047,000**

Table 35: Summary estimated Road Crew savings

5. The difficulties of implementing new Road Crew runs and rosters.

The rosters are planned to be reviewed on October 31st for the Engineers and on the 3rd Monday of November for the Trainmen (*source Crew Dispatching Department*).

However we can wonder if the proposed runs and rosters for the Road Crew are actually going to be implemented exactly as described previously. Indeed some specific points of the runs and rosters may be a source a conflict during the negotiations with the Unions. Also the runs may require some modifications due to other reasons.

The following problems are expected to happen:

- ***Qualification requirement:*** some lines require that the employees have a special qualification to operate on them. This concern the Old Colony lines heading toward Middleborough and Kingston and the Framingham/Worcester line. The qualification is a process that lasts approximately 2 weeks.

The current road crew rosters have 15 regular assignments that require Old Colony qualifications. The new rosters have 23 assignments requiring Old Colony qualifications. At least 15 road crews are already qualified, but it can be difficult to find 8 other road crews that are willing to qualify on this line. However, many employees that are not currently operating on this line actually already have the qualification. The real impact of this problem is therefore hard to estimate accurately but may be not so important. It is currently being reviewed with operations department.

Similarly, the current road crew rosters have 25 regular assignments requiring qualification to Framingham or Worcester. The new rosters have 28 assignments requiring qualification to Framingham or Worcester. Here again many employees who are not currently operating on this line may already be qualified, and as only three more road crews will need to be qualified, this problem is likely to be more insignificant than for the Old Colony line.

Depending on the outcome of the discussions with the Unions on this matter, we may possibly have to try to reduce the number of assignments requiring those specific qualifications. However this is likely that enough employees already have the qualification or will follow the proper training.

- The FRA (Federal Railroad Administration) informed MBCR that they take exception to the way trains are secured at North and South Stations. They want the MBCR to develop a plan to have all arrivals be secured properly according to the Air Brake Instructions. This would change the complexion of the 10-15 minutes turns at South and North Stations and may lead to entirely rework the crew runs and eventually a new time table will have to be put in place.

- A strong opposition of the Unions has to be expected on all the issues that will induce some noticeable changes. In reality many employees are used to the Amtrak's "way of life", especially the long time employees with a high seniority and a strong power in the Unions, and they may not want to see their habits changed.

An important work of management and communication will have to be performed to make the employees accept the changes. MBCR will have to insist on the fact that the modifications of the runs and the rosters are actually a benefit for the employees. Anyway the runs will possibly be modified after discussion with the Unions to try to better reflect their expectations.

III. AC's scheduling: new runs and rosters for assistant conductors.

We will now start the description of the second half of the Crew Scheduling project which concerns the Assistant Conductors. In contrary to the Road Crew runs that have to cover all the trains with no exceptions, the AC's are dispatched in the trains depending on other factors. In this chapter we will first describe the functioning of the AC's dispatching, the specific constraints and the difference between this category of employees and the road crew, the methodology of building runs and rosters and finally the results and the potential savings that ensue.

1. About the AC's dispatching.

In contrary to the road crews, who have to cover all the trains once, the AC's dispatching is really specific and depends on other factors. In reality, the job of an AC consists in helping the conductor verifying the validity of the tickets, looking after the safety of passengers and managing the opening and closing of train doors. We can understand that this help is needed only where the number of passengers is too important for only one conductor, which is the reason why the dispatching is really specific. The number of AC's to be assigned to each train is determined by two agreements.

1.1. The MBTA agreement.

The number of trainmen per trainset as required by the MBTA agreement must comply with the "300 passengers criteria". Practically, this means the following:

- ✓ 1 conductor per trainset with less than 300 passengers;
- ✓ 1 conductor plus 1 assistant conductor per trainset with a number of passengers comprises between 300 and 600;
- ✓ 1 conductor plus 2 assistant conductors per trainset with a number of passengers comprises between 600 and 900;
- ✓ 1 conductor plus 3 assistant conductors per trainset with a number of passengers comprises between 900 and 1200;
- ✓ 1 conductor plus 4 assistant conductors per trainset with more than 1200 passengers.

There can't be more than 4 AC's per train as the maximum number of passengers is limited by the trainset maximum capacity, which corresponds to 1316 seated places with 6 double level cars and 2 single level cars.

Passenger counts are performed regularly, about once a year every September collecting passenger counts for all the trains, and once a year in April collecting passenger counts for all the peak hour trains. They are performed by McMahon Associates, Inc., a transportation engineering and planning firm. *Data of the passenger counts are available in annex S14 and N13.*

1.2. The UTU labor agreement.

The number of passenger trainmen required by the UTU labor agreement is the following:

- ✓ 1 conductor per trainset with only one car open and available for service;
- ✓ 1 conductor plus 1 assistant conductor per trainset with up to 6 cars open and available for service;
- ✓ 1 conductor plus 2 assistant conductors per trainset with 7 cars and more open and available for service;

The number of cars open and available for service is determined as the following:

✓ ***For the Northside:***

- For peak hour trains, all the cars are open and available for service (the number of coaches per trainset is determined by the equipment cycles);
- For off peak trains, the number of cars open and available for service is depending on the passenger counts as below:
  - Maximum passengers per coach at 2/3 full for comfort = Coach capacity * 2/3 = (1);
  - Number of coaches open for service = passenger count / (1);

Let's take the example of the train #64 with a passenger count of 252.
The trainset consists in 7 cars with a total of 805 seats, which gives a car capacity of 115 seats. The comfort criteria determines the maximum number of passengers per coach at 115*2/3 = 76 passengers. The number of cars open for service will be calculated as 252 / 76 = 3.31 which gives 4 cars open for service.

✓ ***For the Southside:***

- For peak hour trains, all the cars are open and available for service (the number of coaches per trainset is determined by the equipment cycles);
- For off peak trains, the number of cars open and available for service is depending on the passenger counts as below:
  - Passengers count < 50 : 1 coach open;
  - 50 < Passengers count < 100 : 2 coaches open;
  - 100 < Passengers count < 200 : 3 coaches open;
  - 200 < Passengers count < 300 : 4 coaches open;
  - 300 < Passengers count < 400 : 5 coaches open;
  - Passengers count > 400 : all coaches open.

1.3. Currently, an inadequate staffing.

The number of trainmen to be assigned to each train will have to comply with the two agreements. With the existing staffing, all Northside trains are compliant with the UTU labor agreement and the MBTA agreement and only 5 Southside weekday trains are not compliant with those agreements. But the biggest concern currently is the overstaffing. Indeed, based on the April 2005 passenger counts from McMahon for the peak hour trains and the September 2004 passenger counts from McMahon for the off peak trains, almost 55% of the Southside trains and 30% of the Northside trains are overstaffed (*see annex S14 and N13, and table 11*).

2. The specific constraints of the AC's scheduling.

The constraints that will have to be taken into account for the development of every run are pretty much identical to the ones described in the Road Crew scheduling chapter, but a few differences can be noticed. The constraints for the AC's runs are the following:

- Covering the trains in compliance with the UTU labor agreement and the MBTA agreement;
- Runs start and end at the same facilities or stations :

In contrary with the road crew runs which all start from a facility, the AC's runs can start either from a facility or a station. For example, whereas the Southside road crew runs have 7 different locations (*see table 5*), the AC's runs have 15 different starting and ending locations (*see annex S15*).

- Compliance with the federal labor laws : identical;
- Compliance with the Union labor agreement :

The only noticeable difference concerns the releases which start 20 minutes after the last train arrival and end 20 minutes before the next train departure (instead of 30 minutes for the road crew).

- Empty moves duration: identical, however we can notice that many of the AC's empty moves are deadhead moves; moreover for most of the runs that start and end at the stations the SU time is 20 minutes before the first train departure and the SO time is 20 minutes after the last train arrival.
- Balance between economic and social aspects: identical;
- Balance between economic and commercial aspects : identical;

The other constraints cited for the road crew do not apply to the AC's.

3. The methodological approach of building the AC's runs.

The work on the AC's runs basically follows the same process than the one for the road crew runs, with one major difference: we came to the conclusion that is was easier to start from the beginning without using the RFP runs.

- Study of the existing runs: empty moves duration, current intervals, usual SU and SO times, et cetera. This important step gives a first idea of what must be done and how it can be done.

- Inventory of the trains to cover based on the two agreements and the most recent passenger counts.
- Use of the same type of excel working sheets model for the runs description, including the description of the trains' arrangement (with for each train its departure and arrival time) including every PX or deadhead moves, name of the facility or station where the run starts and ends, SU and SO times, working time, spread time, release time and paid release time (if necessary). Utilization of a color code for the trains depending on the number of AC's in it.
- Building new weekday runs starting from the RFP that comply with all the constraints, making sure they are compatible with the equipment cycles (No modifications were made to the equipment cycles).
- 1-Verification of the workability of the new runs by the different departments of operations. 2- Modifications that reflect the comments received. Succession of steps 1 and 2 until complete validation of the runs.
- Building new runs for Saturdays and Sundays with the same process, covering the exact same trains than currently (No recent passenger counts are available for the weekend).
- 1-Verification of the workability of the new weekend runs by the different department of operations. 2- Modifications that reflect the comments received. Succession of steps 1 and 2 until complete validation of the runs.
- Utilization of the same excel working sheet model to build the roster using the new weekday and weekend runs and perform the cost calculation at the same time. Validation of the roster by the Crew Dispatching department.
- Performing the costs analysis.

4. Results of the AC's scheduling project.

4.1. New AC's runs.

4.1.1. New AC's runs for the Southside.

- ***What are the needs in AC's:***

After the analysis of the passenger counts and of the number of cars open and available to service, we were able to determine the needs in terms of AC's for each trains (*see annex S14*).

Number of trains requiring…	1 AC	2 AC's	3 AC's	4 AC's	Total coverage
Inbound	68	18	12	1	144
Outbound	79	18	6	2	141
Total	**147**	**36**	**18**	**3**	**285**

Table 36: Overview of the Southside AC's staffing needs

A minimum of 285 trains will have to be covered by the AC's weekday runs, the main difference with the road crew runs being that 1 train can count up to 4 AC's depending on the number requested. But this total is actually far from the eventual amount of covered train. In fact the inbound trains mainly require AC's during the morning peak-hours, whereas the outbound trains mainly require AC's during the evening peak-hours. Therefore we will have to introduce in the runs many trains that do not actually need any AC's, just to allow to bring the employee back when he covered an outbound or to carry him to the station where the next inbound will start. We will thus not be able to entirely suppress the overstaffing but at least we will try to minimize it.

- ***Weekday's runs:***

The final proposed set of crew runs for assistant conductors comprises 85 runs (*see annex S15*). All those 85 runs were found workable and compliant with all the constraints.

ASSISTANT CONDUCTORS		Weekday Southside runs overview		
		Current	Proposal	Variation
Number of runs		**93**	**85**	**-8**
Spread	*< 8 hours*	*6*	*7*	*+1*
	[8-10] hours	*12*	*11*	*-1*
	[10-12] hours	*23*	*23*	*-*
	[12-15] hours	*46*	*40*	*-6*
	> 15 hours	*6*	*4*	*-2*
Average spread		**11:50**	**11:42**	**-1%**
Total regular		744:00	680:00	**-9%**
Total overtime		40:42	4:48	**-88%**
Total release		434:25	465:47	+7%
Total paid release		*212:26*	*175:04*	***-18%***
Split runs percentage		**73%**	**85%**	**+16%**
Overstaffing		**53%**	**23%**	**-57%**

Table 37: Overview of the Southside AC's weekday's runs characteristics

Many observations can be made from the table above. First of all, the AC's can cover all the required trains with only 85 runs, compare to 93 runs currently. This is mainly due to a significant reduction of the overstaffing, which decreases by almost 60%. Only 63 trains need to be overstaffed to compensate the excess of inbound trains to be covered in the morning and the excess of outbound trains in the evening peak-hours. The reduction of the runs number is therefore really significant.

If the spread distribution and average are quite similar between the two sets, it is highly interesting to notice that the amount of paid hours of overtime and release decrease significantly. Indeed, the overtime is almost totally suppressed with a reduction of nearly 90%, while the paid release is going down by almost 20%. Speaking of that it is interesting to notice that although the paid release decrease, the total release time increases. Indeed 85% of the runs of the proposed set are split, against 73% of split runs for the current set. This is the reason why the total amount of release time increases, and as the actual average working time of the split runs is shorter in average for the new set

(5:58 against 6:27 for the current set), this explain why less hours of release are paid. Those runs tend to be a lot more split than the road crew runs as the needs of AC's are basically concentrated on the morning and evening peak-hours only, so they are in release during the off-peak hours.

- ***Weekend's runs:***

The proposed Saturday's and Sunday's runs were built starting from the current weekend runs (*see annex S16 and S17*). As no recent passenger counts were available for the weekend, we decided to cover the exact same trains than currently with the same number of AC's in each trains. Given the number of current Extra Assignments (11), we also came to the conclusion that we would create two more runs for the Saturday's and two more runs for the Sunday's. This would allow suppressing all the extra assignments from the roster while creating three new weekly assignments. Moreover this will help to significantly reduce the overtime.

ASSISTANT CONDUCTORS	Saturday Southside runs overview		
	Current	Proposal	Variation
Number of runs	**20**	**22**	**+2**
Spread *< 8 hours*	*2*	*6*	*+4*
[8-10] hours	*9*	*11*	*+2*
[10-12] hours	*6*	*2*	*-4*
[12-15] hours	*3*	*3*	*-*
Average spread	**10:06**	**9:19**	**-8%**
Total regular	160:00	176:00	+10%
Total overtime	27:22	11:11	**-59%**
Total release	16:19	30:36	+88%
Total paid release	*14:43*	*14:07*	***-4%***

Table 38: Overview of the Southside AC's Saturday's runs characteristics

ASSISTANT CONDUCTORS	Sunday Southside runs overview		
	Current	Proposal	Variation
Number of runs	**15**	**17**	**+2**
Spread *< 8 hours*	*2*	*7*	*+5*
[8-10] hours	*8*	*8*	*-*
[10-12] hours	*4*	*2*	*-2*
[12-15] hours	*1*	*0*	*-1*
Average spread	**9:48**	**8:34**	**-13%**
Total regular	120:00	136:00	+13%
Total overtime	21:39	8:42	**-60%**
Total release	6:25	8:25	+31%
Total paid release	*6:25*	*4:59*	***-22%***

Table 39: Overview of the Southside AC's Sunday's runs characteristics

This approach of the restructuring based on the augmentation of the number of runs to eventually suppress the extra assignments in the roster is doubly profitable. As a matter of fact in addition of suppressing the extra assignments, this allows reducing the overtime

significantly. This reduction is up to 60% for both Saturdays' and Sundays' runs, which more than compensate the increase of regular hours.

Moreover, we can notice the same phenomenon than for the weekday's runs, saying that even though the number of hours of release increase significantly, the hours of release eventually paid decrease in both case as the actual working time of the split runs is shorter for the proposed set (6:43 against 7:44 for the Saturday's set).

4.1.2. New AC's runs for the Northside.

- ***What are the needs in AC's:***

Number of trains requiring…	1 AC	2 AC's	Total coverage
Inbound	66	8	82
Outbound	69	7	83
Total	**135**	**15**	**165**

Table 40: Overview of the Northside AC's staffing needs

A minimum of 165 trains will have to be covered by the AC's weekday runs (*see annex N13*). Again this total is not the final amount of covered train as we will need to voluntarily overstaff to compensate the excess of inbounds in the morning and outbounds in the evening peak-hours.

- ***Weekday's runs:***

The final proposed set of crew runs for assistant conductors comprises 43 runs (*see annex N14*). All those 43 runs were found workable and compliant with all the constraints, and the table below shows an overview of their characteristics.

ASSISTANT CONDUCTORS	Weekday Northside runs overview		
	Current	Proposal	Variation
Number of runs	**46**	**43**	**-3**
Spread *< 8 hours*	*2*	*4*	*+2*
[8-10] hours	*14*	*14*	*-*
[10-12] hours	*10*	*8*	*-2*
[12-15] hours	*20*	*17*	*-3*
Average spread	**11:07**	**10:56**	**-1.5%**
Total regular	368:00	344:00	**-7%**
Total overtime	26:08	12:05	**-54%**
Total release	144:45	166:32	+15%
Total paid release	*93:45*	*66:55*	***-29%***
Split runs percentage	**61%**	**70%**	**+15%**
Overstaffing	**28%**	**13%**	**-54%**

Table 41: Overview of the Northside AC's weekday's runs characteristics

The observations that can be made from the table above are pretty much the same than the ones for the Southside with a reduction of the runs number by 3, a significant diminution of the overtime and of the paid release time by respectively almost 55% and 30%, an augmentation of the percentage of split runs, and finally a reduction of the overstaffing by more than 50%.

- ***Weekend's runs:***

Similarly to the Southside, we came to the conclusion that we would create two more runs for the Saturday's (*see annex N15*) and two more runs for the Sunday's (*see annex N16*) as it would allow suppressing all the extra assignments from the roster while creating one new weekly assignments and reducing the overtime at the same time.

ASSISTANT CONDUCTORS		Saturday Northside runs overview		
		Current	Proposal	Variation
Number of runs		**17**	**19**	**+2**
Spread	*< 8 hours*	*1*	*4*	*+3*
	[8-10] hours	*11*	*10*	*-1*
	[10-12] hours	*4*	*5*	*+1*
	[12-15] hours	*1*	*0*	*-1*
Average spread		**9:36**	**9:05**	**-5%**
Total regular		136:00	152:00	+12%
Total overtime		20:42	5:03	**-76%**
Total release		6:45	24:57	+270%
Total paid release		*6:45*	*11:58*	*+77%*

Table 42: Overview of the Northside AC's Saturday's runs characteristics

ASSISTANT CONDUCTORS		Sunday Northside runs overview		
		Current	Proposal	Variation
Number of runs		**14**	**16**	**+2**
Spread	*< 8 hours*	*2*	*5*	*+5*
	[8-10] hours	*5*	*6*	*-*
	[10-12] hours	*7*	*5*	*-2*
	[12-15] hours	*0*	*0*	*-1*
Average spread		**9:37**	**8:55**	**-7%**
Total regular		112:00	128:00	+14%
Total overtime		18:20	7:56	**-57%**
Total release		2:30	14:04	+463%
Total paid release		*2:10*	*6:41*	*+208%*

Table 43: Overview of the Northside AC's Sunday's runs characteristics

Here again the approach of the restructuring based on the augmentation of the number of runs to eventually suppress the extra assignments in the roster allows reducing the overtime significantly. This reduction is up to 75% for the Saturdays' set and 60% for the Sundays' set, which more than compensate the increase of regular hours and the increase of paid release hours. Effectively in this case the restructuring didn't allow reducing at the same time both the overtime and the paid release.

4.2. *New AC's rosters.*

The crew rostering process for assistant conductors is identical than the one for the road crew. The constraints also are the same, and we will still try to reduce the number of extra assignment while inserting them in the regular weekly assignments.

4.2.1. New AC's rosters for the Southside.

The table below summarizes the main figures relative to the current and the proposed rosters for the AC's of the Southside. *The proposed roster is available in annex S19.*

AC's SOUTHSIDE	*Weekday runs*	*Saturday runs*	*Sunday runs*	Regular assignments	Extra assignments	Other assignments	Extra Board
Current	*93*	*20*	*15*	98	11	2	12
Proposal	*85*	*22*	*17*	93	0	2	17
Variation	***-8***	***+2***	***+2***	**-5**	**-11**	**-**	**+5**

Table 44: Comparison of the Southside rosters characteristics

The main information in this table is the fact that the number of regular assignments is reduced by 5. This can be easily explained: on one hand the cut of 8 weekdays' runs suppress 8 regular assignments, but on the other hand the addition of the 4 new weekend runs and the 11 current extra assignments gives 15 runs that can be inserted in the roster creating 3 new regular assignments. This is this difference between the 8 assignments suppressed and the 3 assignments created that eventually cut the roster by 5 regular assignments. It therefore results in the growth of the Extra Board by 5 new employees. The other assignments concern the two Terminal Switchers and are not modified.

4.2.2. New AC's rosters for the Northside.

The table below summarizes the main figures relative to the current and the proposed rosters for the AC's of the Northside. *The proposed roster is available in annex N18.*

AC's NORTHSIDE	*Weekday runs*	*Saturday runs*	*Sunday runs*	Regular assignments	Extra assignments	Other assignments	Extra Board
Current	*46*	*17*	*14*	52	1	1	9
Proposal	*43*	*19*	*16*	50	0	1	11
Variation	**-3**	**+2**	**+2**	**-2**	**-1**	**-**	**+2**

Table 45: Comparison of the Northside rosters characteristics

The rostering of the proposed set of runs induce the suppression of two regular assignments, resulting in the growth of the Extra Board by 2 new employees. The other assignment concerns an Engine Terminal and is not modified.

4.3. *The costs forecasting.*

4.3.1. About the AC's wages calculation.

The wages calculation is strictly identical for the AC's than for the road crew. All the assumptions made for the road crew cost calculation are still valid for the AC's.

Assistant Conductors	
regular rate	$21.65
overtime rate	$32.48
release rate	$10.83

Table 46: Hourly rates for the assitant conductors, effective July 1st 2005
Source: Payroll Department

4.3.2. Important potential savings expected for the Southside.

- ***Regular assignments' costs:***

AC's SOUTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation
Average Daily Pay	**$ 213**	**$ 197**	**-7%**
Total regular	$ 86,770	$ 80,540	-7%
Part of regular	*81.4%*	*87.9%*	
Total release	$ 11,690	$ 9,680	-17%
Part of release	*11.0%*	*10.6%*	
Total overtime	$ 8,200	$ 1,425	-83%
Part of overtime	*7.7%*	*1.6%*	
Total AC's	**$ 106,660**	**$ 91,645**	**-14%**

Table 47: Cost forecasting for the Southside AC's regular assignments

The total costs of the wages for the assistant conductors of the Southside decrease by more than 14%. This decreasing is basically half way due to the significant reduction of the overtime by more than 80%, and half way due to the cut of 5 regular assignments which contribute to the diminution of 7% of the regular costs. It is interesting to notice that the part of the overtime in the wages costs goes from almost 8% to less than 2%.

The other interesting information is the fact the average pay for the Engineers and the Conductors only decreases by 7%, whereas the total cost decreases by 14%, mainly because of the large reduction of the overstaffing.

- ***Extra Board's costs:***

The cost of 6th and 7th days for the South AC's is determined proportionally at 60% of the trainmen cost. It is interesting to notice that whereas the Extra Board growths by 5 employees, the overall cost decreases because of the diminution of the average daily pay and the suppression of the 6th and 7th days related costs.

AC's SOUTH EXTRA BOARD COST	Average daily pay	Five Days Cost	Total Five Days	6th and 7th cost	Total Cost
Current (12)	$ 213	$ 1,065	$12,780	$4,700	**$17,480**
Proposal (17)	$ 197	$ 985	$16,745	$0	**$16,745**

Table 48: Cost forecasting for the Southside AC's Extra Board

➢ ***Overall roster's costs:***

The following table summarizes the global cost of the roster, including the other types of crew and the extra boards, as well as the potential savings resulting from the implementation of those new runs and rosters for the assistant conductors.

TOTAL COSTS AC's SOUTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation	Weekly savings	Annual savings
Total Assistant Conductors	$ 97,850	$ 91,755	-14%	$ 15,015	**$ 780,780**
Total Other Crew	$ 2,705	$ 2,705	-	-	-
Total Extra Board	$ 17,480	$ 16,745	-4.2%	$ 735	$ 38,220
Total Southside AC's Roster	**$ 126,845**	**$ 111,095**	**-12.4%**	**$15,750**	**$819,000**

Table 49: Total Southside AC's cost forecasting

From those figures we can see that the potential savings linked to the implementation the new runs and rosters for the assistant conductors on the Southside are expected to be superior to **$800,000** per year. This represents a diminution of more than 12% of the costs for the AC's operations.

4.3.3. Costs also go down significantly for the Northside.

➢ ***Regular assignments' costs:***

AC's NORTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation
Average Daily Pay	**$ 214**	**$ 198**	**-7%**
Total regular	$ 45,205	$ 43,300	-4%
Part of regular	*81.1%*	*87.5%*	
Total release	$ 5,170	$ 3,825	-26%
Part of release	*9.3%*	*7.7%*	
Total overtime	$ 5,365	$ 2,385	-56%
Part of overtime	*9.6%*	*4.8%*	
Total AC's	**$ 55,740**	**$ 49,510**	**-11%**

Table 50: Cost forecasting for the Northside AC's regular assignments

The total costs of the wages for the assistant conductors of the Northside decrease by more than 11%. Here again this decreasing is both due to the significant reduction of the overtime and to the cut of 2 regular assignments that both result from the reduction of the overstaffing.

➢ ***Extra Board's costs:***

AC's NORTH EXTRA BOARD COST	Average daily pay	Five Days Cost	Total Five Days	6th and 7th cost	Total Cost
Current (9)	$214	$1,070	$9,630	$2,590	**$12,220**
Proposal (11)	$198	$990	$10,890	$0	**$10,890**

Table 51: Cost forecasting for the Northside AC's Extra Board

Here again it is interesting to notice that the augmentation of the Extra Board by two more employees actually induces a reduction of the costs.

➢ ***Overall roster's costs:***

The following table summarizes the global cost of the roster, including the other types of crew and the extra boards, as well as the potential savings resulting from the implementation of those new runs and rosters for the assistant conductors.

TOTAL COSTS AC's NORTHSIDE	Weekly Cost Current	Weekly Cost Proposal	Variation	Weekly savings	Annual savings
Total Assistant Conductors	$ 55,740	$ 49,510	-11%	$ 6,230	**$ 323,960**
Total Other Crew	$ 1,510	$ 1,510	-	-	-
Total Extra Board	$ 12,220	$ 10,890	-10.9%	$ 1,330	$ 69,160
Total Northside AC's Roster	**$ 69,470**	**$ 61,910**	**-10.9%**	**$ 7,560**	**$393,120**

Table 52: Total Northside AC's cost forecasting

The potential savings for the AC's operations on the Northside amount to almost **$400,000** a year, which represents a diminution of the costs by 11%.

4.3.4. Conclusion.

If we consider the whole network, the potential savings linked to the implementation of the new rosters for the Assistant Conductors are superior to **$1,200,000** per year.

ESTIMATED ANNUAL SAVINGS SUMMARY	Southside	Northside	Total
Total AC's	**$ 819,000**	**$ 393,000**	**$ 1,212,000**

Table 53: Summary estimated AC's savings

5. The difficulties of implementing new schedules for the AC's.

The same problems can be expected for the implementation of the new rosters than the ones detailed in the Road Crew chapter, except for the qualification issue as the assistant conductors don't need any qualification to operate on the Framingham/Worcester and on the Old Colony lines.

IV. Conclusion on the Crew Scheduling project: great potential savings.

The following table summarizes the different potential savings by side and category. The costs include the wages related to the other type of crew as well as the wages related to the Extra Board. We can see that the overall potential savings for the network's operations linked to the implementation of the new runs and rosters exceed **$2,250,000** per year. This corresponds to a diminution of the passenger operations' costs by almost 7%. This amount takes into account the diminution of 6th and 7th days due to the growth of the Extra Board and the suppression of the extra assignments. However we can also expect less Hours of Service; that would eventually lead to other savings that are not taken into account here.

SUMMARY	Weekly Costs Current	Weekly Costs Proposal	Variation	Annual savings
Engineers South	$ 147,000	$ 140,000	-4.7%	$ 356,000
Conductors South	$ 113,500	$ 108,000	-5.0%	$ 294,000
AC's South	$ 127,000	$ 111,000	-12.4%	$ 819,000
Total South	**$ 387,500**	**$ 359,000**	**-7.3%**	**$ 1,469,000**
Engineers North	$ 106,000	$ 102,000	-4.0%	$ 220,000
Conductors North	$ 82,000	$ 78,500	-4.2%	$ 177,000
AC's North	$ 69,500	$ 62,000	-10.9%	$ 393,000
Total North	**$ 257,500**	**$ 242,500**	**-5.9%**	**$ 790,000**
Total Network	**$ 645,000**	**$ 601,500**	**-6.7%**	**$ 2,259,000**

Table 54: Total Network cost forecasting, the potential savings of the crew scheduling project

At the end of this chapter dedicated to the Crew Scheduling and Rostering project, we can understand the importance of this specific aspect of the crew management in the Railroad Transportation. In fact an effective utilization of the available human resources greatly improves a railroad transit operation's reactivity and service quality, minimize the overall roster costs, and can improve both customers and employees satisfaction as long as we keep in mind that a viable crew schedule has to be a balance between the commercial, social and economic aspects.

PART 3: ABSENTEEISM AND VACATION ANALYSIS

MBCR produces a weekly overview of the absenteeism, but no there is no follow-up that would provide an overview over a longer period of time. This would actually allow having a better knowledge of the absenteeism and therefore making some accurate forecasting. One outcome of such a forecasting could be the optimization of the Extra Board that could be built to respond more efficiently to the needs. Moreover, the current vacation system basically spreads the vacations of all the MBCR's employees over six months, which can induce some operations' problems as a great number of employees are in vacation at the same time, therefore leading to a lack of crew at some period of the year and an increase of the operations' costs.

Consequently this chapter will propose two analyses, the first one focused on having an accurate and efficient absenteeism overview the second one investigating new vacation systems.

I. The Absenteeism Analysis.

The main objective of this analysis is to produce accurate data on the absenteeism that would give an overview of every type of absences for every type of employees over a long period of time. The outcome is to able to make some accurate forecasting of the absenteeism based on the averages over the analysis horizon.

1. The methodological approach.

This analysis will be performed by filling an Excel worksheet with the data contained in every absenteeism overview produced weekly. This worksheet will have to be built in the most exhaustive way and will give an overview of the absenteeism over a year. The model we end with basically consists in a calendar, with the days from Monday to Sunday horizontally and the weeks vertically. Each day is divided in many columns corresponding to each kind of absences, using the absence codes currently used by the crew dispatchers. Within each day of each week, we therefore translate the data from the weekly absenteeism overview by incrementing the appropriate box corresponding to one kind of absence by one every time an absence of this exact kind on this exact day occurs. There are four different worksheets corresponding respectively to the Southside Engineers (*see annex S21*), the Southside Trainmen (*see annex S22*), the Northside Engineers (*see annex N20*) and the Northside Trainmen (*see annex N21*), which are the four categories used in the MBCR's absenteeism weekly overviews.

2. The different types of absence.

Within each day, six main categories of absence can be isolated. Then each category can be divided into sub-categories, eventually leading to a really accurate overview.

The main and sub categories of absences, along with the codes used by the Crew Dispatchers and the associated payments, are the following (*source Crew Dispatching Department*):

- ***Vacation*** (*VAC - 1/52nd of last years earnings*)***;***
- ***Training;***
  - ✓ Qualifying (*QUA - 8 hours pay*);
  - ✓ Recertification Class (*ERC - Pay of assignment*);
  - ✓ Training Class (*ETC - Pay of assignment*);
- ***Approved Absence;***
  - ✓ Union Business (*BLE - No pay*);
  - ✓ Care Program for Crews involved in an accident (*CARE – 3 days pay of assignment*);
  - ✓ Company Business (*COB - Pay of assignment*);
  - ✓ Jury Duty (*JUR - Pay of assignment*);
  - ✓ Bereavement (*BRV - 8 hours pay*);
  - ✓ Personal Day (*PLD - 8 hours pay*);
  - ✓ Relief Day (*REL - Day off*);
- ***Long Term Absence;***
  - ✓ Family and Medical Leave (*FMLA - No pay*);
  - ✓ Railroad Injury (*INJ - No pay*);
  - ✓ Off Further Notice (*Off FN – No pay*);
  - ✓ Military Leave (*MIL – No pay*);
- ***Unauthorized Absence;***
  - ✓ Sick (*SIK – No pay*);
  - ✓ Absence Without Leave (*AWL – No pay*);
  - ✓ Dropped Assignment (*DROP – No pay*);
  - ✓ Refused to Work (*RCA – No pay*);
  - ✓ Unexcused (*UNX – No pay*);
- ***Other;***
  - ✓ Hours of Service (*HRS - 8 hours pay*);
  - ✓ Out of Service (*OOS – No pay*);
  - ✓ Other (*Call Not Used - 4 hours pay, as long as they are available for the entire day; Displaced from Job – No pay*).

3. The analysis spread.

For now, this analysis has been performed over 30 weeks, from December 6th 2004 to July 3rd 2005. Practically, this means that the data contained in each of those 30 absenteeism weekly overviews have been imported into the different worksheets. All the following charts will thus be representative of this period, and every averages mentioned in this chapter are calculated over those 30 weeks (*see annex S23, S24, N22 and N23*).

4. Overview of the different kinds of absenteeism over the analysis spread.

➢ *Vacation analysis:*

The following charts describe the number of employees in vacation for one week over the analysis spread. It has been built by dividing the total weekly amount of vacation days by five, so it gives an average number of employees in vacation for one complete week (e.g. 5 days off). This is not totally representative of the reality as many employees take from one to four days and not a complete week, however this is more significant.

- Southside:

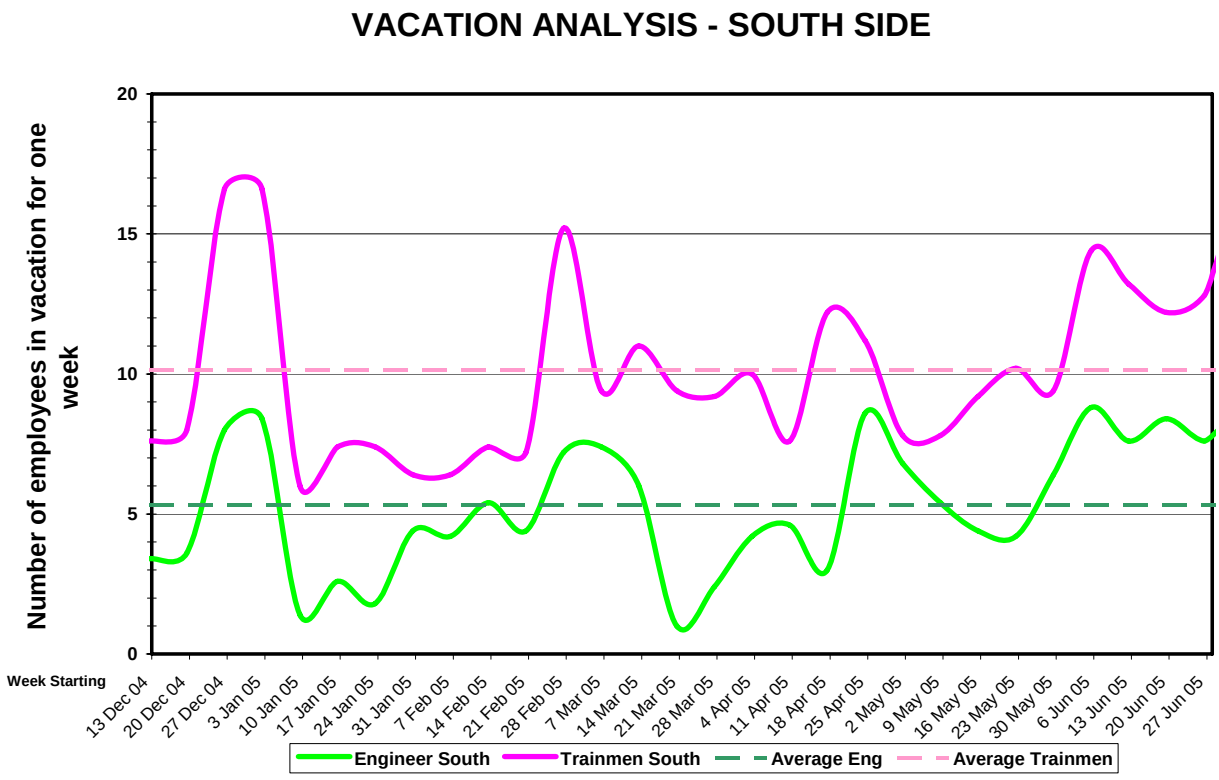

Figure 9: Southside vacation evolution

We can notice that the aspect of this graphic is pretty much similar for both the engineers and the trainmen of the Southside. We can isolate some peaks of vacations around Christmas, end of February, Easter, and also notice a growth anticipating the upcoming summer vacations.

Between December and July the max peak is in Christmas with around 10% of the human resource (17 trainmen and 9 engineers) having one week of vacation. On average over this 30 weeks spread, around 10 trainmen and 5 engineers are in vacation every week.

- Northside:

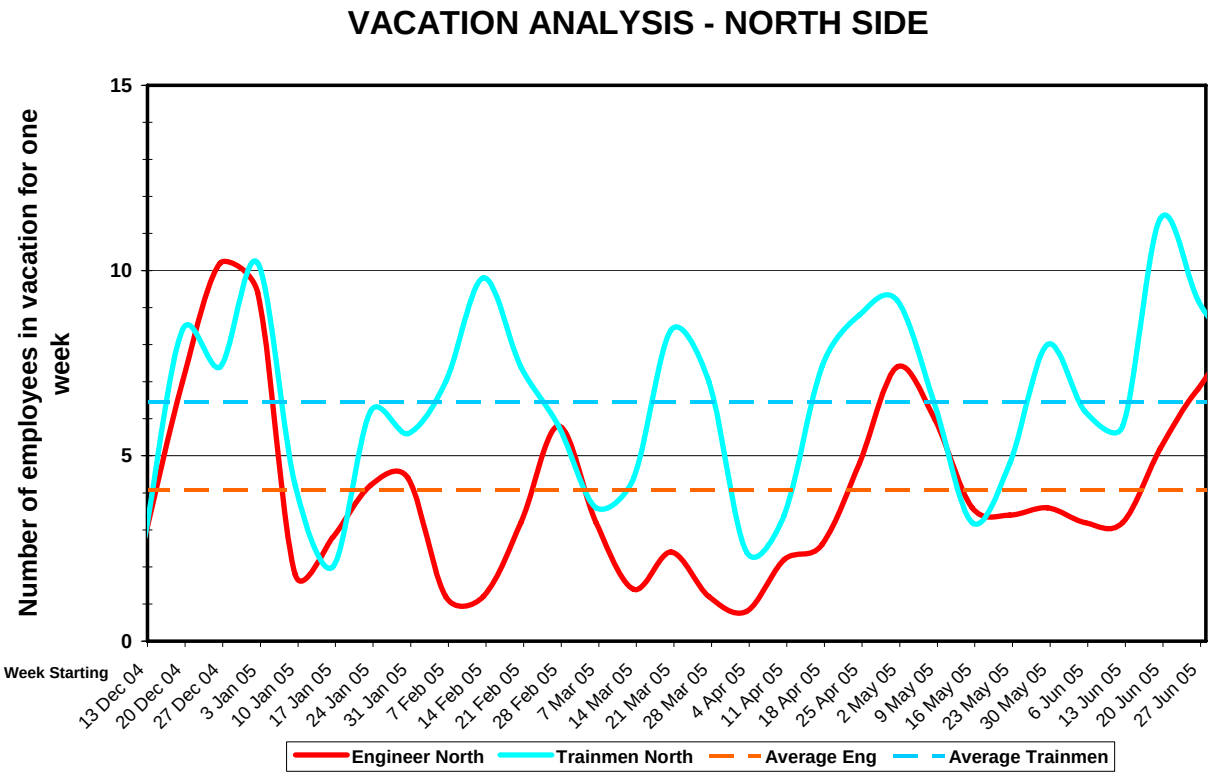

Figure 10: Northside vacation evolution

As opposite to the Southside, it is a little surprising to notice that the aspect of this graph shows more peaks of vacation, especially for the Trainmen. We can still notice the peak during Christmas as well as a growth before the upcoming summer vacation, but the peaks between them are also at a pretty high level. Moreover the global evolution reflects many differences between the engineers' and the trainmen's vacations.

During the Christmas peak, almost 16 % of the engineers are in vacation for a week compare to only 8% of the trainmen. In average, around 4 engineers and 6 trainmen are in vacation every week on the Northside.

- Daily analysis:

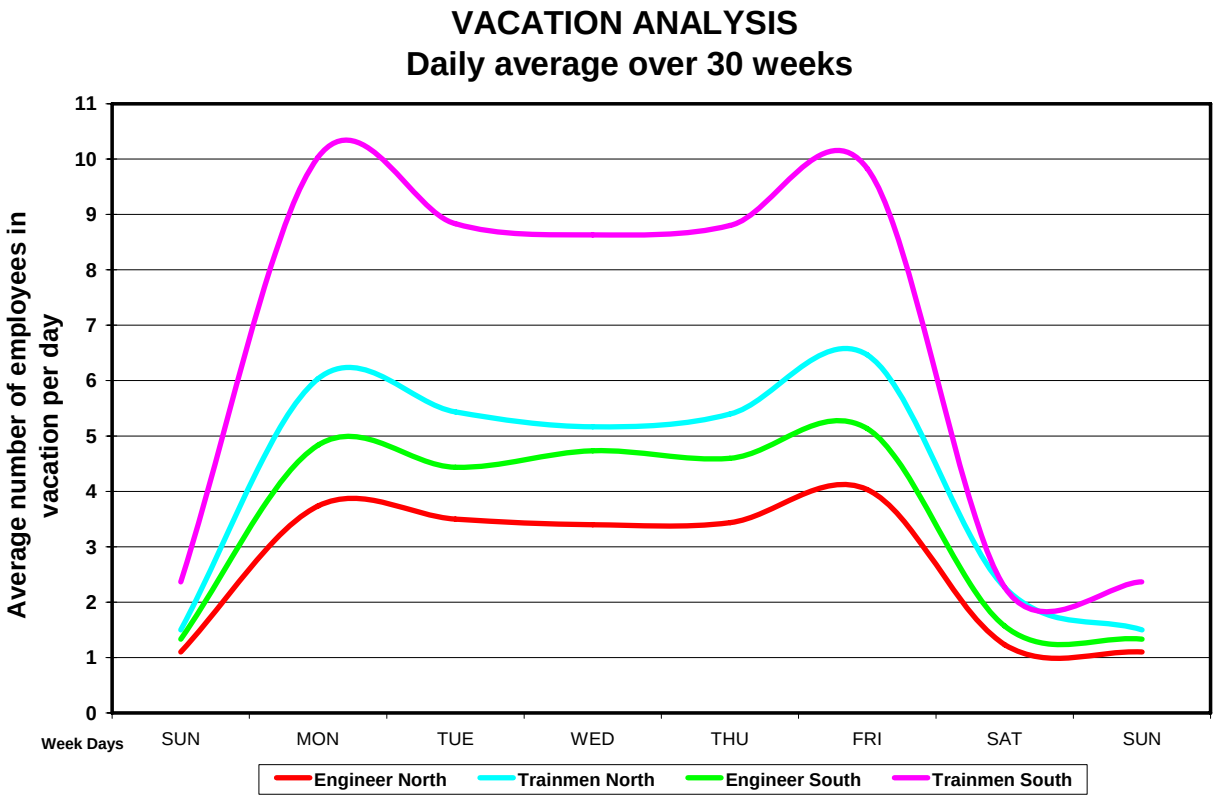

Figure 11: Vacation's daily variation

This chart describes the average daily evolution of the vacation. This has been built by averaging the number of vacation days for each day of the week over the 30 weeks of the study. The main observation that we can make is that there are peaks of vacations during the Monday and during the Friday, meaning that many employees are only taking one or two days of vacation to extend their weekend. Also the number of days of vacations taken during the weekend is much smaller than during the week.

- ***Long Term absenteeism analysis:***

This type of absenteeism is pretty rare, so no charts will be useful to describe it. The table below summarizes the maximum number of employees that have been absent for a long term at the same time.

LONG TERM	Max simultaneous absenteeism	
	Southside	Northside
Engineers	2	1
Trainmen	3	1

Table 55: Maximum simultaneous absenteeism overview

➢ ***Training analysis:***

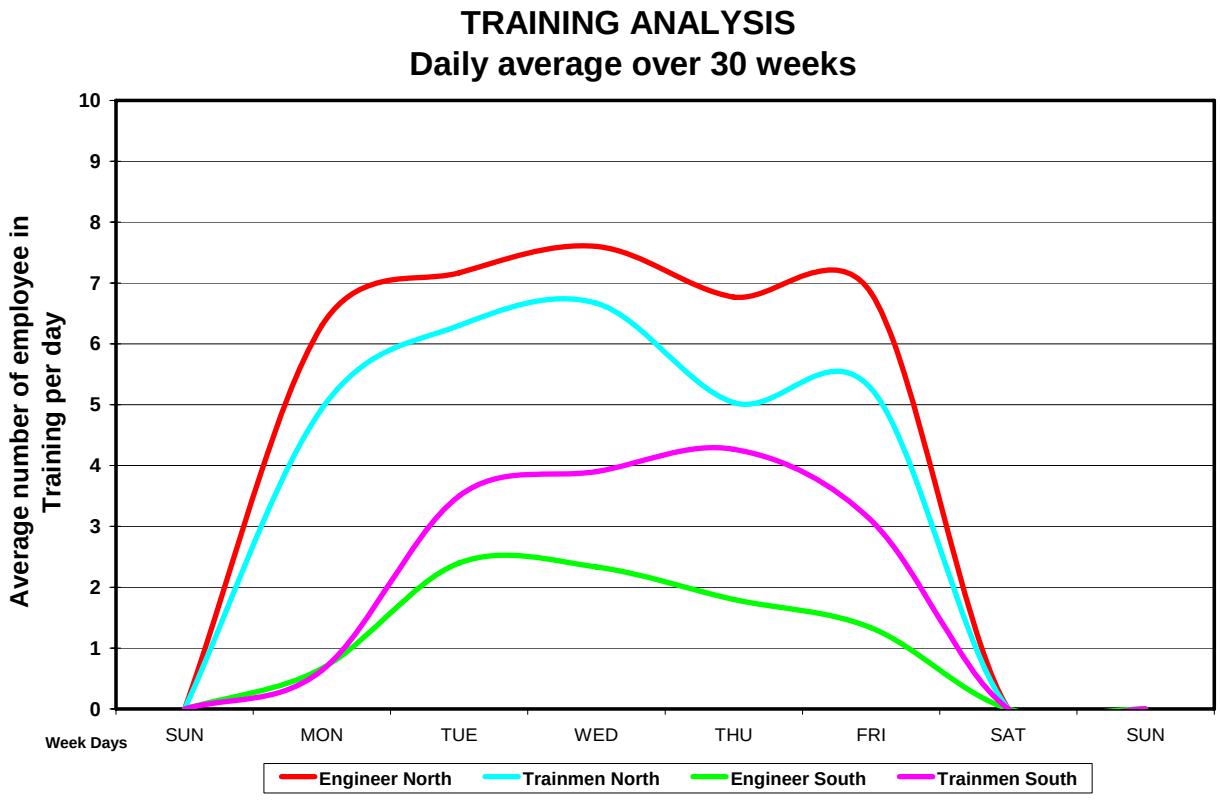

Figure 12: Training's daily variation

It is interesting to notice that the training is in average twice more important on the Northside than on the Southside. Regarding the graph above, we can say that the engineers from the Northside get more training than anyone else, with an average of 7 people every day, and that this training is more or less constant over the week. Concerning the Northside trainmen, the average is around 6 employees in training each day, with a peak during the Wednesdays. The training on the Southside is mainly spread between the Tuesdays and the Thursdays and only concerns a small number of employees, around four trainmen and two engineers in average.

We can also add that within the total training for the Engineers of the Northside, two employees are having a long term qualification, which lasts almost a year. Those two employees will be deduced in all the further analyses regarding the Northside engineers as they don't reflect an unpredictable absenteeism.

➢ ***Approved absence analysis:***

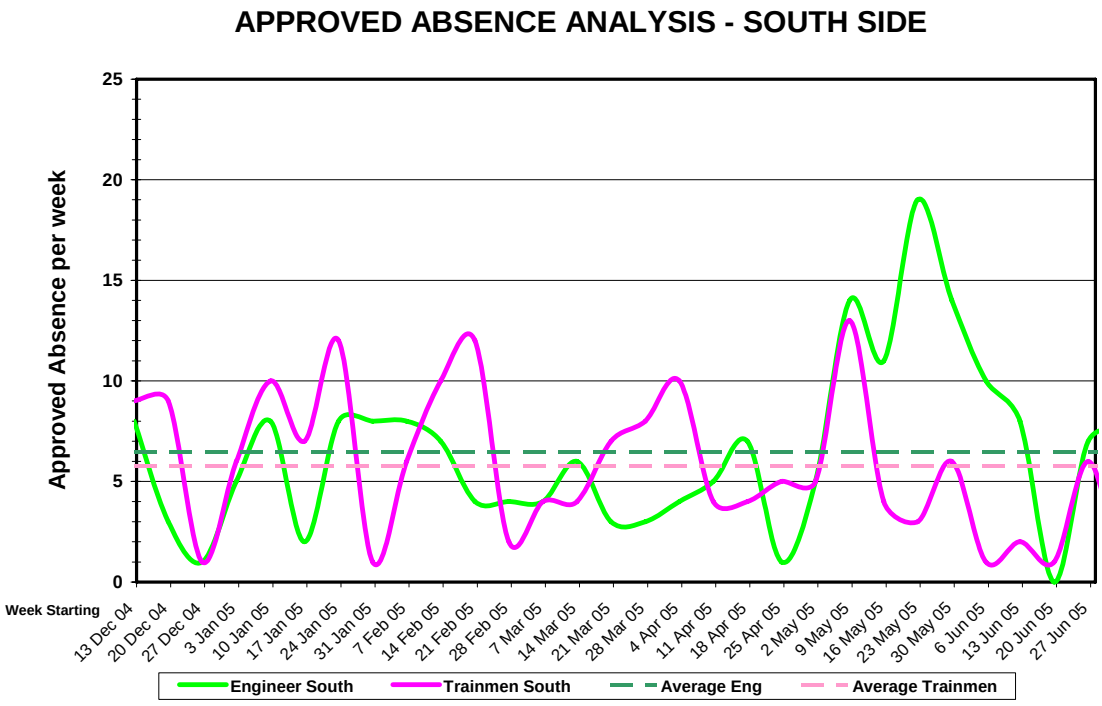

Figure 13: Southside approved absence evolution

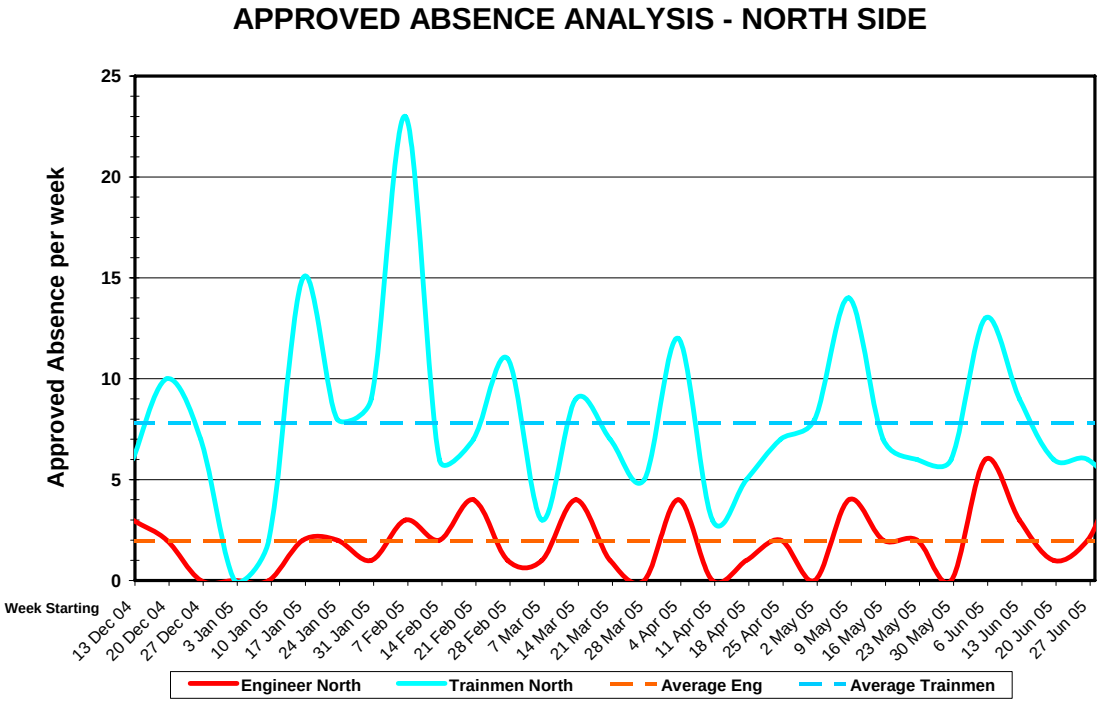

Figure 14: Northside approved absence evolution

Figures 13 and 14 depict the weekly variation of the approved absenteeism for Southside and Northside. We have to underline that as opposite to the vacation's graphs those represent the number of days off per week due to approved reasons, and not a number of employees absent for a week.

We can notice that this variation is really chaotic and can vary within a large range, from no approved absence per week up to 23 absences per week for example in the case of the Northside trainmen. On average, we can notice that the number of approved absences per week for the Southside is around 6 for both categories, which represents around one approved absence per day. On the contrary, the evolution concerning the engineers and trainmen of the Northside is pretty different as the engineers have almost no approved absenteeism (2 absences of that kind per week in average) whereas the trainmen have the strongest rate with approximately 8 approved absences per week.

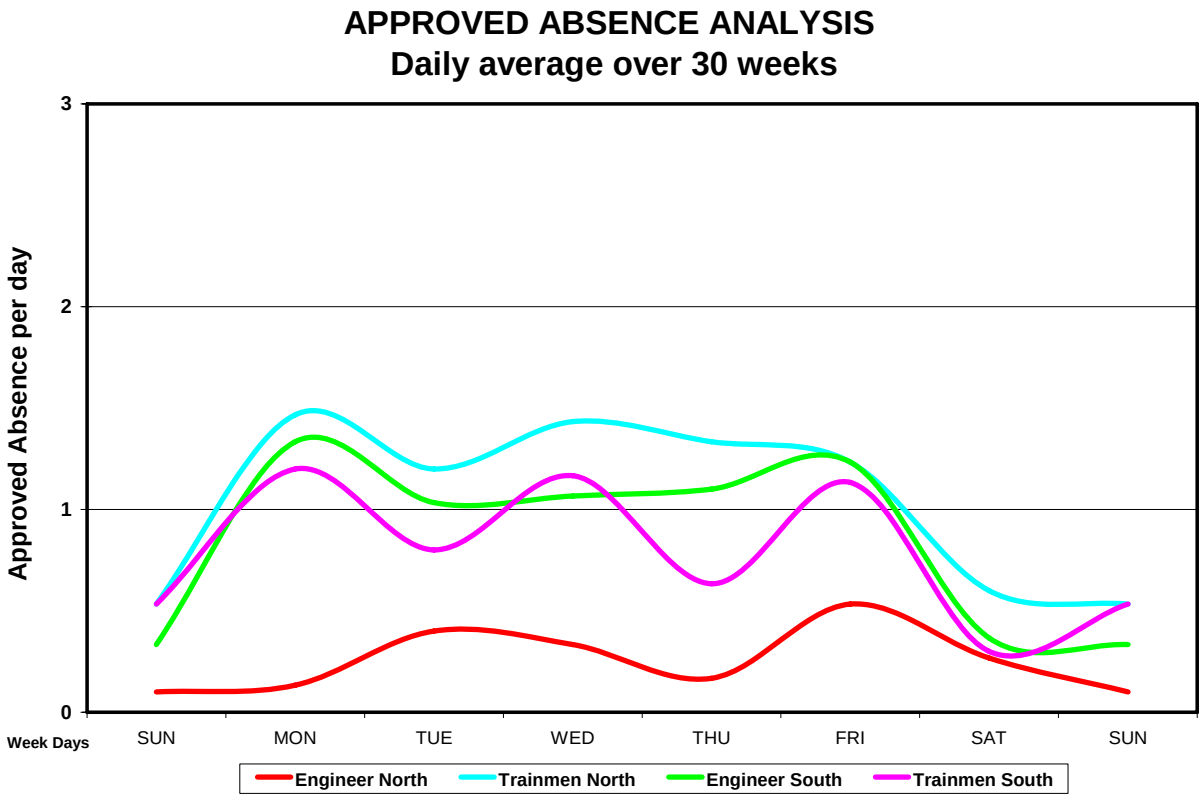

Figure 15: Approved absence's daily variation

This graph shows that the approved absences are basically equally spread over the week between Monday and Friday, with only a small peak on Monday. This kind of absenteeism is almost insignificant compare to the vacation or the training for example, especially for the Northside Engineers.

➢ ***Unauthorized absence analysis:***

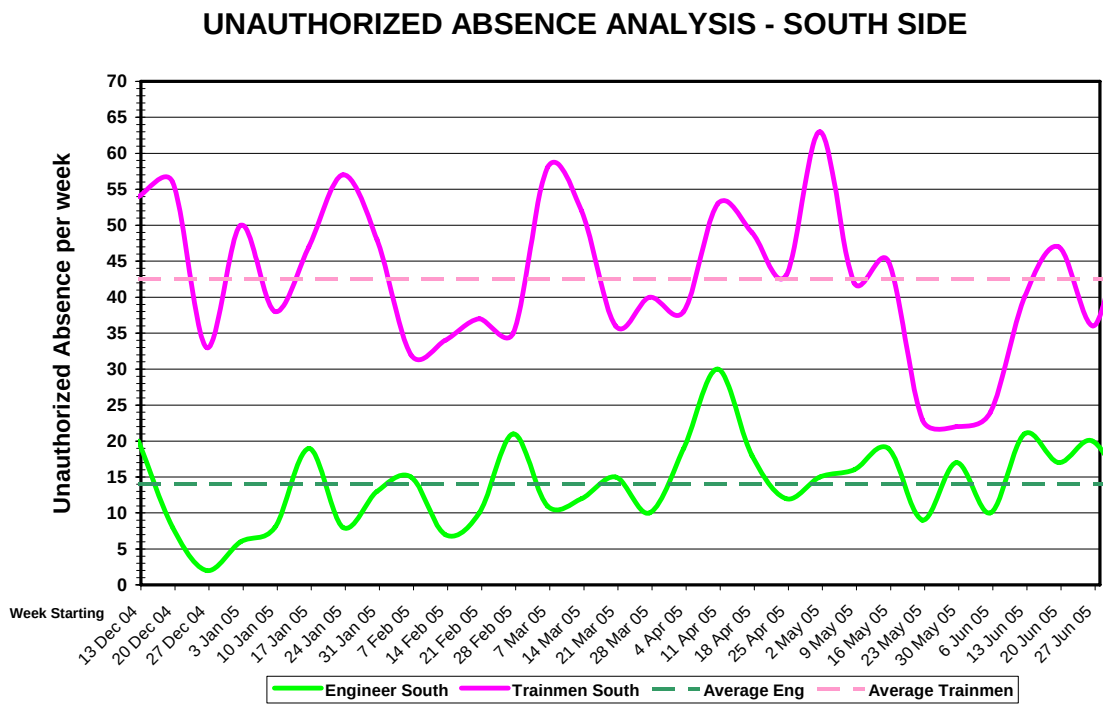

Figure 16: Southside unauthorized absence evolution

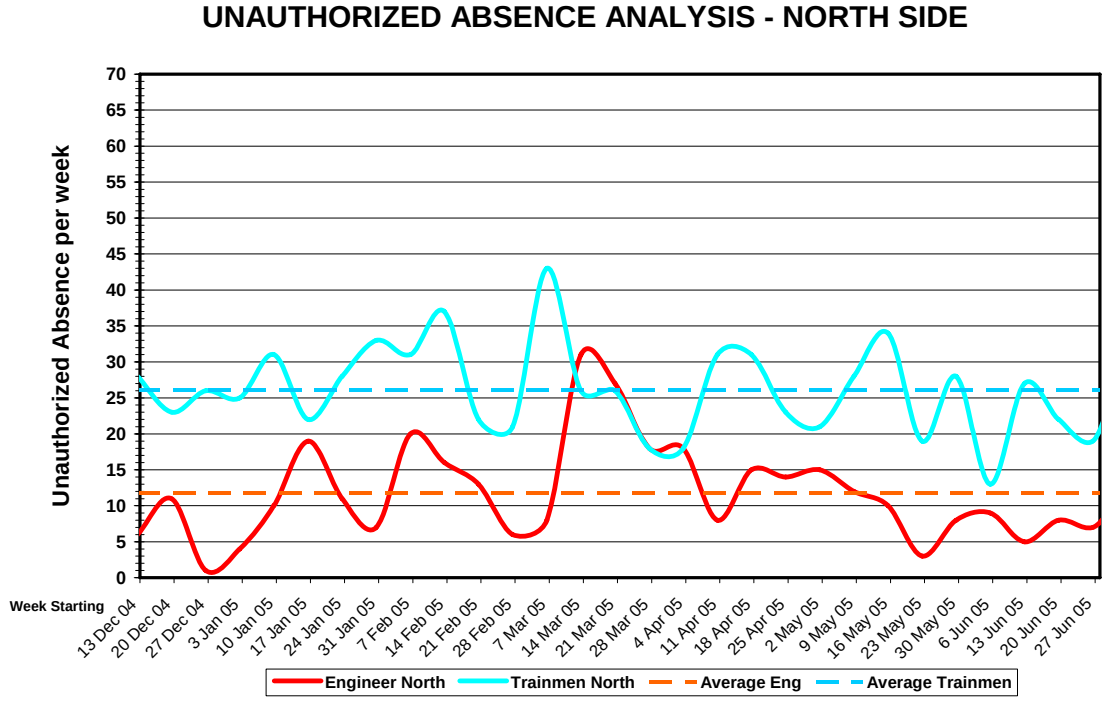

Figure 17: Northside unauthorized absence evolution

We can notice that for both sides the unauthorized absenteeism is quite significant. For the Southside, the average number of days off per week due to unauthorized reasons amounts to 45 for the trainmen and 15 for the engineers. Concerning the Northside, the figures are smaller but still reach 25 for the trainmen and 12 for the engineers. The unauthorized absenteeism is far more important than every other kind of absenteeism (except the vacation and training). As a matter of comparison, we can calculate that the unauthorized absenteeism during the weekdays is in average only 85% superior to the approved absenteeism for the Southside engineers, but twice more important for the Northside trainmen and up to 6 times more important concerning the Northside engineers and the Southside trainmen.

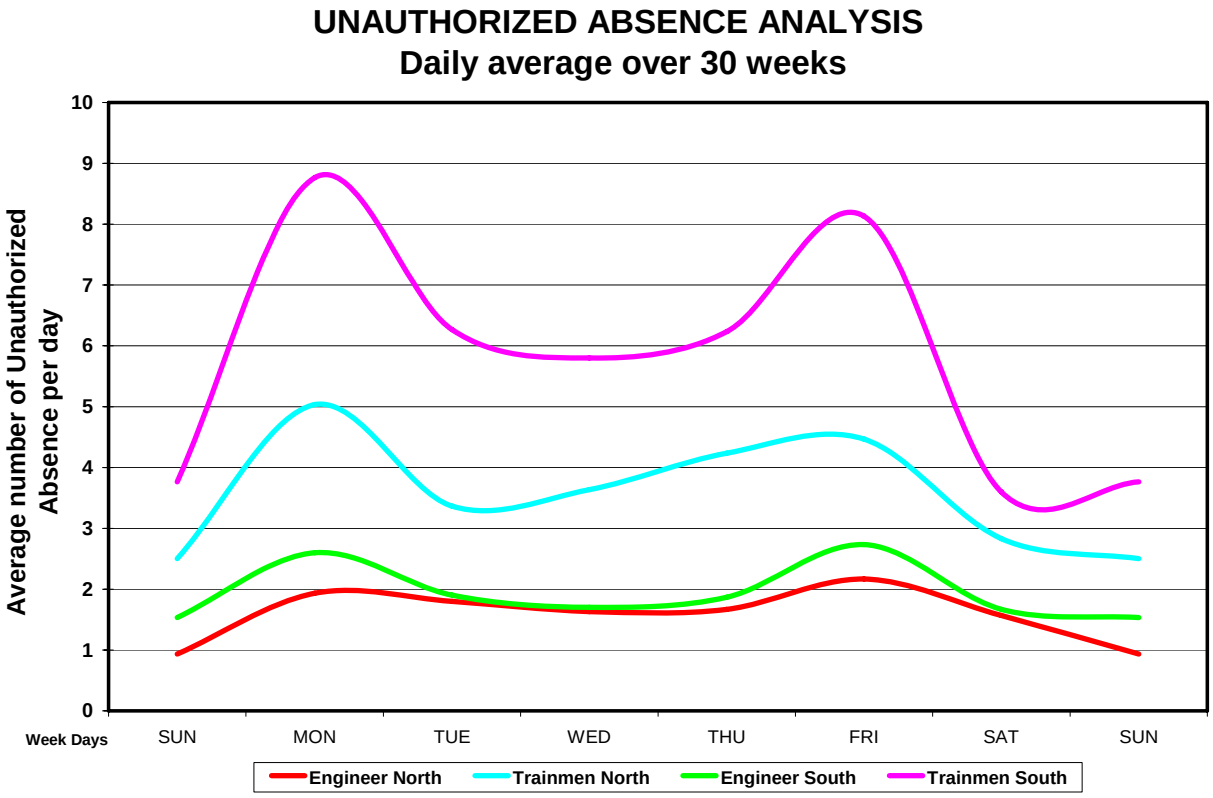

Figure 18: Unauthorized absence's daily variation

If we focused on the repartition of unauthorized days off over a week we can basically observe the same kind of curves than on the vacation graphs, with two peaks of absenteeism on Monday and on Friday. This effect is particularly noticeable for the Southside with a Monday's absenteeism for example more than 40% superior to the average absenteeism from Tuesday to Thursday, for both engineers and trainmen. This can be explained as Monday and Friday are the worst days for people marking off in order to have a longer weekend.

The last thing we can add is that the unauthorized absenteeism basically only consists in unexcused absence and sickness, with respective parts of 42% and 56% in average.

➢ ***Other absenteeism analysis:***

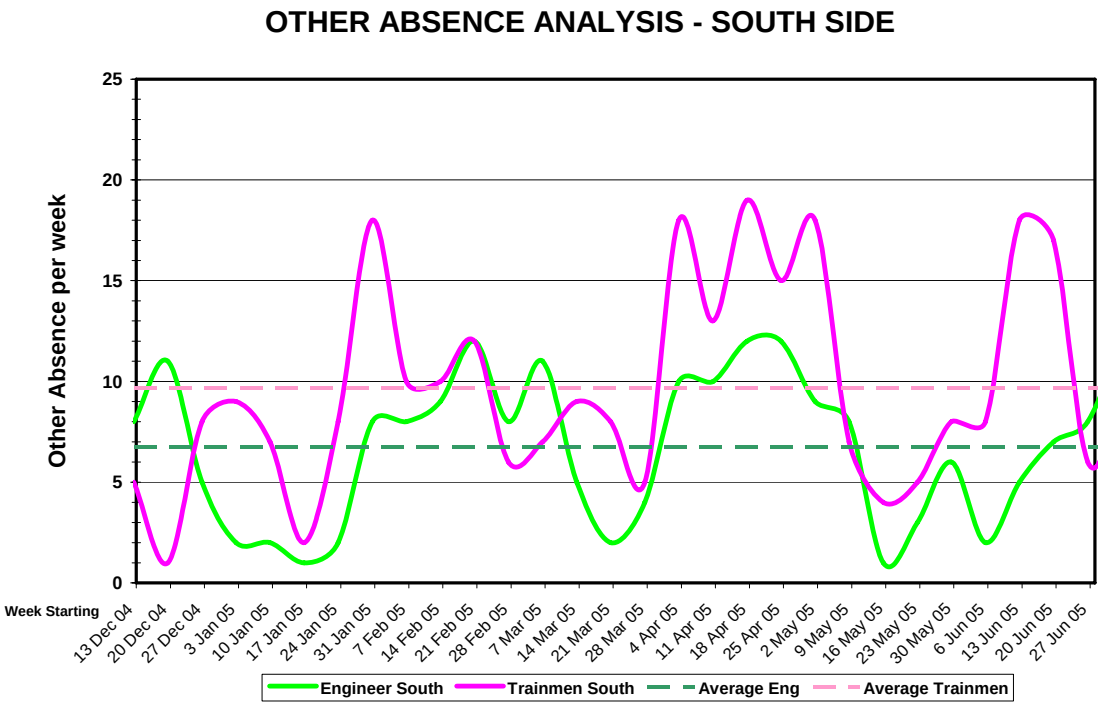

Figure 19: Southside other absence evolution

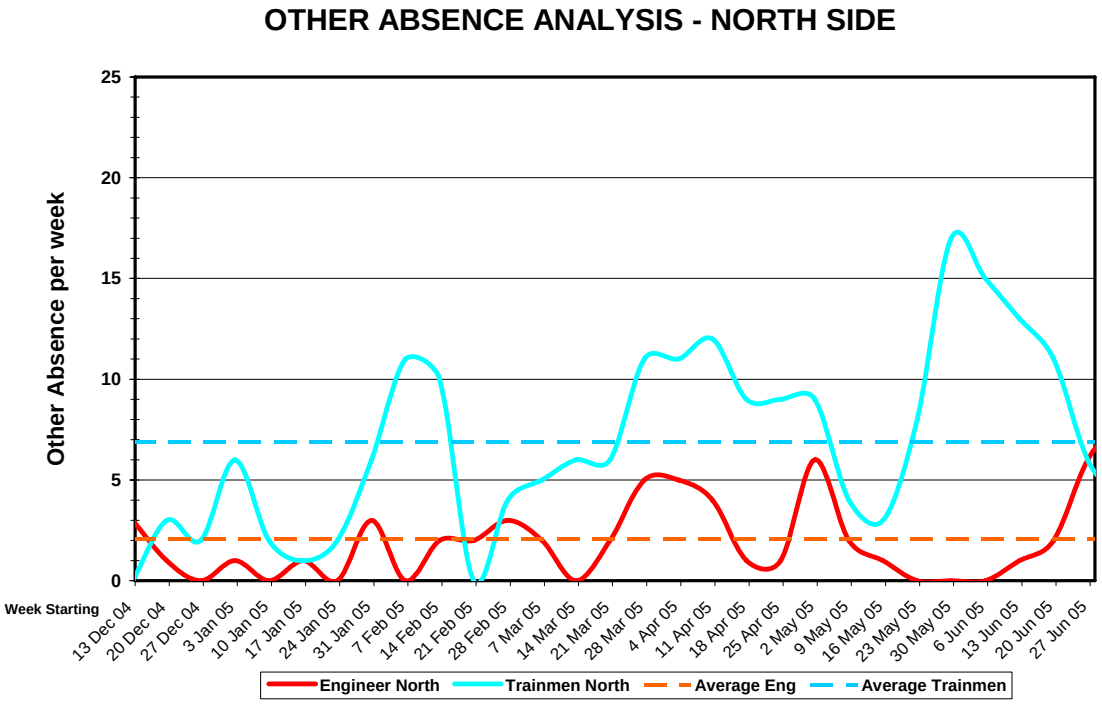

Figure 20: Northside other absence evolution

We can notice a quite chaotic evolution of the other type of absences, which are mainly due to the Hours of Service occurring when the duty time exceeds the legal working time. The rest of this absenteeism is due to the employees being put Out of Service, but is less important than the HOS except for the Northside trainmen. The OOS occur as a punishment when an employee did something wrong (company policy violation for example), and are at the origin of the peaks noticeable for the trainmen of South and North sides. Effectively the HOS evolution is more stable in the time.

Speaking of which, it seems important to analyze the curves below as it gives us interesting information. In fact it clearly appears that more Hours of Service occurs during the Mondays and the Saturdays. They are mainly produced by the people marking off on Mondays and Fridays.

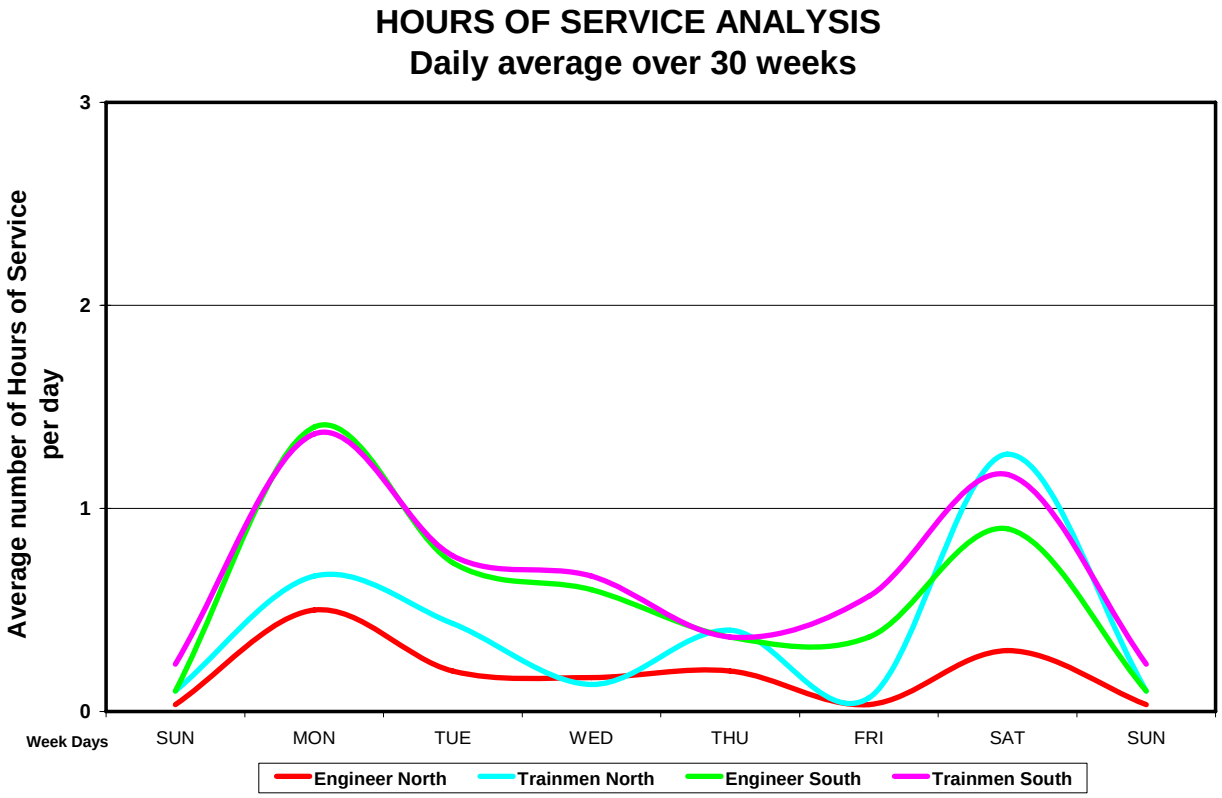

Figure 21: Hours of Service daily variation

5. Conclusion: Total Absenteeism Analysis.

The following charts have been built by dividing the total amount of absenteeism days by five, so the curves basically represent the number of employees that have been off for a week for any reasons, including the vacations.

- Southside:

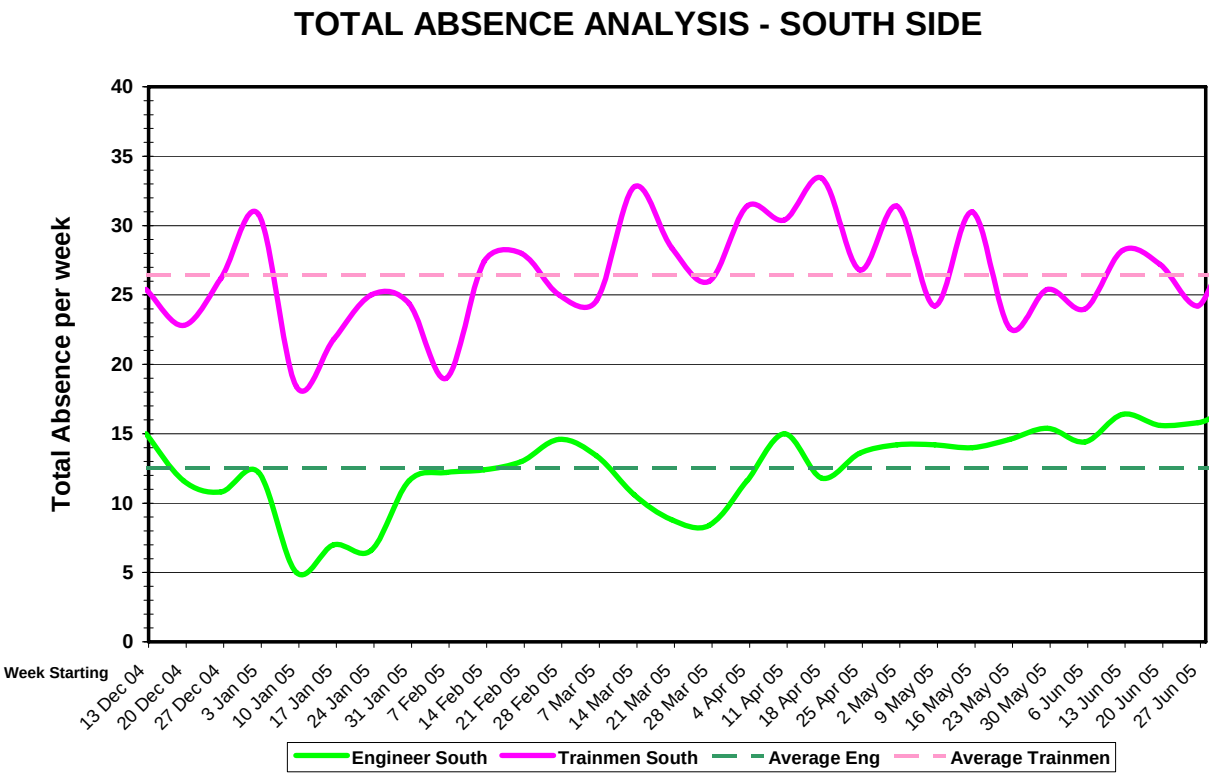

Figure 22: Southside total absenteeism evolution

When we sum all the kind of absenteeism, the global aspect of the curves is smoother and less chaotic than all the individual curves for each type of absence. Speaking about figures, we can say that in average around 12 engineers and 26 trainmen are absent for one week every week. This represents less than 15% of the regular payroll.

SOUTHSIDE	Weekly Average	Standard Deviation	Value (1) = AVG+STD	% of weeks below (1)	Max absenteeism
Engineers	12.5	3	15.5	93%	16.4
Trainmen	26.5	3.7	30.2	80%	33.4

Table 56: Standard deviation of the Southside weekly absenteeism

The table above shows the standard deviation of the weekly values around the average, as well as the percentage of weeks with absenteeism smaller than the sum of the average

and the standard deviation. This table proves that an Extra Board that could absorb the average absenteeism plus the standard deviation would be sufficient in more than 80% of the time for the trainmen and 93% of the time for the engineers. Moreover the extreme peak values are very close to this limit, so that if the Extra Board is not sufficient the number of 6th and 7th days will be small anyway.

- Northside:

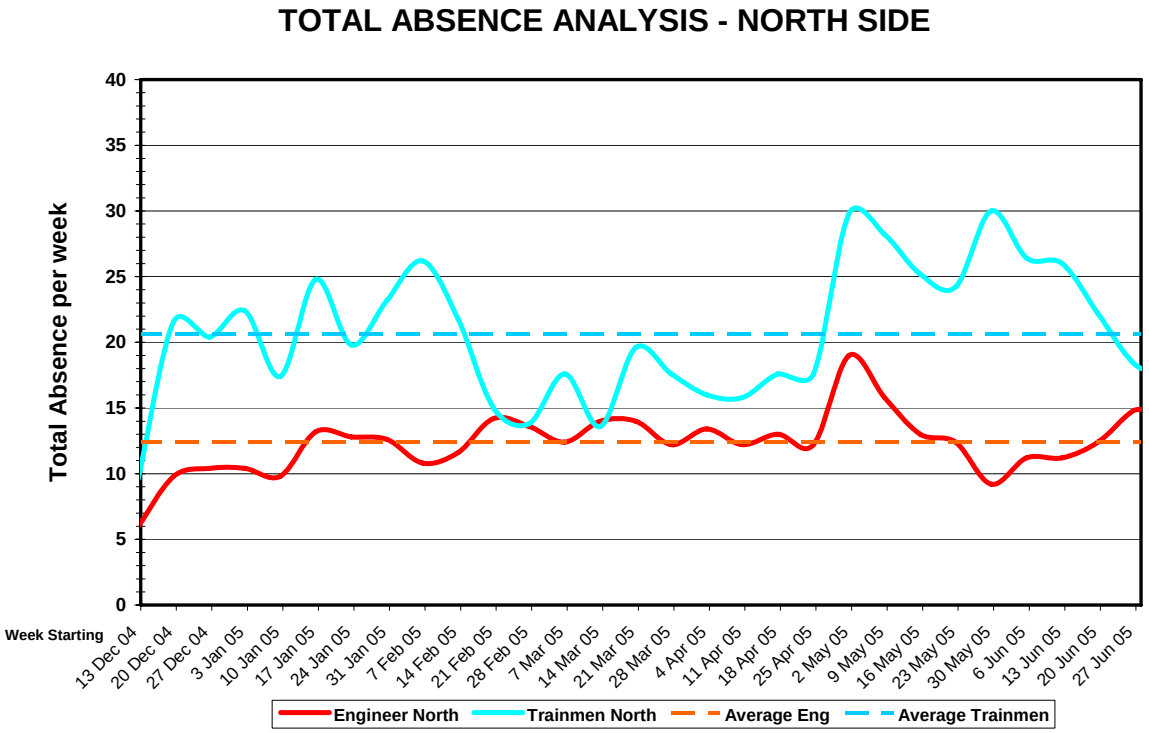

Figure 23: Northside total absenteeism evolution

For the Northside also the global aspect of the curves is smoother and less chaotic than all the individual curves for each type of absence. This is especially true for the Engineers, and all the peaks for the Trainmen absenteeism are due to a big amount of employees in training. Speaking about figures, we can see that in average around 12 engineers and 21 trainmen are absent for one week every week. This represents approximately 19% of the payroll for engineers and 17% for trainmen, which are higher rates than for the Southside.

NORTHSIDE	Weekly Average	Standard Deviation	Value (1) = AVG+STD	% of weeks below (1)	Max absenteeism
Engineers	12.5	2.3	14.8	93%	19
Trainmen	20.6	5.1	25.7	80%	30

Table 57: Standard deviation of the Northside weekly absenteeism

The table above leads to the same conclusion than table 56. It also confirms that for both sides, the dispersion of the values around the average is larger for the trainmen.

- Daily analysis:

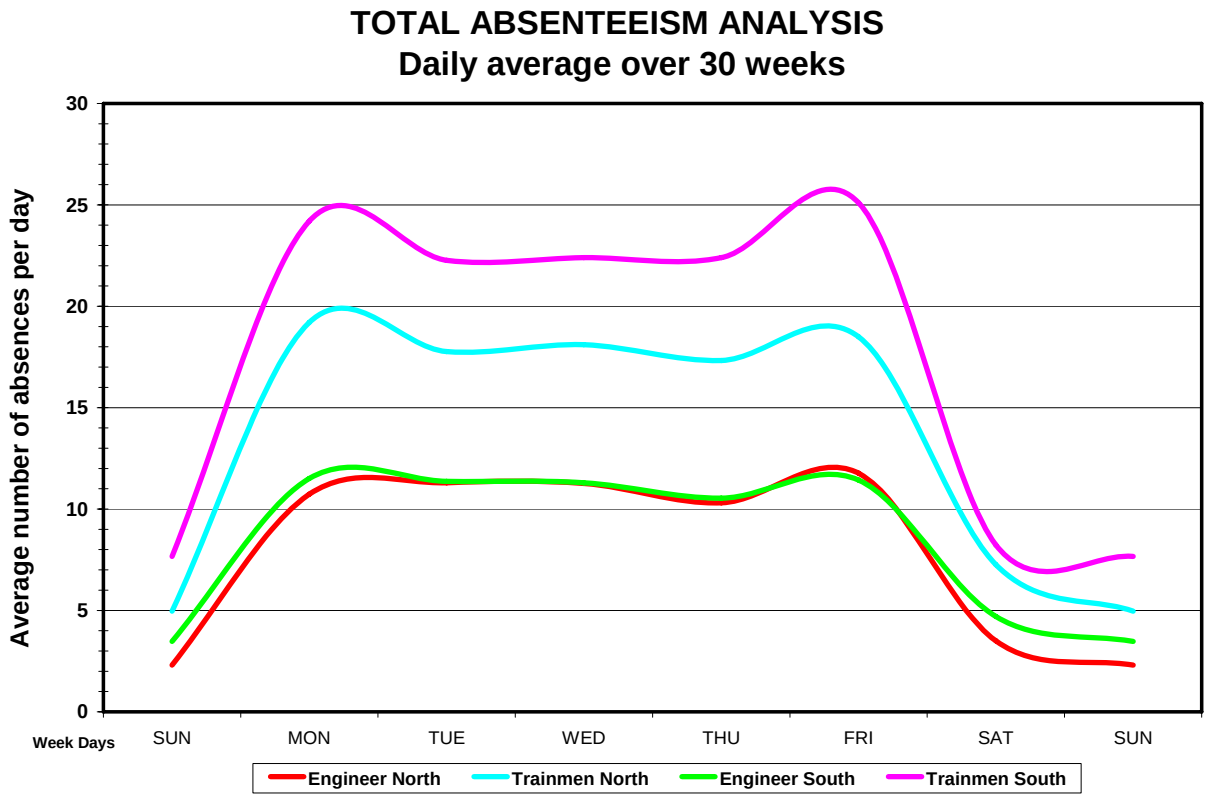

Figure 24: Total absenteeism's daily variation

This graph once again highlights peaks of absences on Mondays and on Fridays, for all sides and all categories of employees. Also it is interesting to remark that the absenteeism of engineers of South and North sides are almost identical. This seems strange at first sight as the payroll on the Southside is bigger, however it can be easily explained by the training, which is much more important on the Northside. In fact, without taking into account the two long term training, there are in average three more engineers in training everyday in the Northside than in the Southside.

- Conclusion:

UNAVAILABILITY RATE	Southside	Northside
Engineers	14.6 %	19.2 %
Trainmen	13.7 %	16.6 %

Table 58: Average unavailabitlity rate summary

This table highlights the average unavailability rate which is calculated as the ratio between the weekly average absenteeism and the current crew resource (Southside: 86 engineers and 194 trainmen; Northside: 65 engineers and 125 trainmen – *source HR Dpt*).

II. The vacation analysis.

The following study has been performed by Elie TAMBOU. The results of this study will be displayed here as there will be useful in the further investigation about the Extra Boards. Two scenarios have been investigated, one that consists in equally distribute the vacation weeks all over the year (instead of spreading them in a shorter period of time as currently), and the other one that consists in allowing a number of days depending on the average length work. Let's take the example of an employee working 11H a day. Instead of converting his allowed hours of vacation (which are determined based on the seniority) into 8 hours day as it is done currently, they would be converted into 11 hours day. On the other hand this employee would still get paid 11 hours a day instead of 8 hours. The main difference with this system is that the employee is getting paid more overall (each week of vacation he will get are paid on an 11 hours daily basis) but has less vacation (for instance 88 allowed hours of vacation would be converted into 8 days of vacation with the 11 hours basis, instead of 11 days with the current system). This is a benefit for the employee who earns more money and for the employer who takes advantage of a larger human resource at all time.

1. Scenario 1: Vacation spread over a year.

The table 59 summarizes the number of employees in vacation for one week every week in the case where vacations are equally spread over one year, taking into account the current seniority of the employees. The spread is the only difference compared to the current system, therefore the number of days allowed are calculated on an 8 hours basis. The table 60 is identical but takes into account the evolution of the seniority rate between 2005 and 2006. Also note that the South Engineers category includes current trainees for next year and those with only 1 year seniority (40hours each).

SCENARIO 1 - 2005	Vacation allowed in hours	Weekly number of employees on vacation for a full week.
Engineers South	13080	6
Trainmen South	23120	11
Engineers North	8960	4
Trainmen North	13280	6

Table 59: Vacation forecasting for 2005 with scenario 1

SCENARIO 1 - 2006	Vacation allowed in hours	Weekly number of employees on vacation for a full week.
Engineers South	13280	6
Trainmen South	23480	11
Engineers North	9000	4
Trainmen North	14320	6

Table 60: Vacation forecasting for 2006 with scenario 1

The number of hours allowed in 2006 based on the new seniority does not increase a lot so that the average number of employees in vacation every week remains identical.

2. Scenario 2: Allowed hours of vacation converted into days using the average daily working time basis.

For a reason of simplification and because it is close to the average length of a current working day, an 11 hours basis to convert hours allowed into days will be applied to all the categories of employees. If this system should be implemented, the number of days allowed would be calculated individually based on the actual working time of each employee. The 11 hours basis is strictly arbitrary.

SCENARIO 2 - 2005	Vacation allowed in hours	Weekly number of employees on vacation for a full week.
Engineers South	13080	4
Trainmen South	23120	8
Engineers North	8960	3
Trainmen North	13280	4

Table 61: Vacation forecasting for 2005 with scenario 2

SCENARIO 2 - 2006	Vacation allowed in hours	Weekly number of employees on vacation for a full week.
Engineers South	13280	4
Trainmen South	23480	8
Engineers North	9000	3
Trainmen North	14320	5

Table 62: Vacation forecasting for 2006 with scenario 2

For this scenario again the average number of employees in vacation each week does not change between 2005 and 2006 except for the Northside Trainmen. But the main information that those tables provide is the fact that the number of employees in vacation every week (this scenario still use the assumption of scenario one, knowing that weeks of vacation are spread over a year) significantly decreases, by almost 30% (actually 27% which is the variation between 8 and 11 hours). This means that the employer would benefit of more human resource every day and thus would be able to use it more efficiently. Moreover the overall pay of the employees would increase too as they would be paid 55 hours every week of the year instead of 55 hours when they are working and 40 hours when they are in vacation. However this issue has never been discussed with the Unions yet so it is not possible to assume that it can be implemented someday.

PART 4: EXTRA BOARD ANALYSIS

This chapter will combine the results from all the previous analysis to try to find an answer to the real needs of MBCR in terms of Extra Board. In fact today everyone agrees that the current Extra Boards are not sufficient to compensate the absenteeism of both sides and both categories of employees, inducing a lot of 6th and 7th days. MBCR is currently willing to hire new persons in order to dispose of larger Extra Boards. They went to the conclusion that each Extra Board list should be as big as 25% of the regular staff. This investigation will combine all the previous results to try to determine the most efficient number of employees required in each Extra Board. We will study the current situation as well as the proposed situation if the new rosters should be implemented. All the results in this chapter are meant to be a help for MBCR to decide what they really need, and likewise the crew scheduling project results they are just a proposal.

I. Estimation of the required Extra Boards for the current network.

For tables 63 to 66, all the following assumptions will be made:

- The vacation number (first column) is based on the vacation analysis (*see table 59*) from Monday to Friday and on the vacation average for the Weekend (*see figure 11*).
- The daily absenteeism number (second column) is calculated as following: total daily absenteeism number – daily vacation number + daily standard deviation calculated for each day over the 30 weeks (*see figures 25 to 28*). We then establish the closest integer as the daily absenteeism number (*see annex S23, S24, N22 and N23 – XTRA ESTIMATION row*).
- The current Extra Board column reflects the number of Extra Board employees on duty based on the current rosters.
- The Required Extra Board column is the sum of the vacation number and the daily absenteeism number, plus the extra assignments number if necessary.
- The trainmen figures combine the absenteeism of the conductors and of the assistant conductors. We will assume that the repartition of the absenteeism for each category is proportional to the number of employee in each category. For the Southside, around 40% of the absenteeism is due to the conductors and the other 60% represent the AC's absenteeism. For the Northside, about half of the absenteeism is due to the conductors and the other half to the AC's.
- Daily absenteeism coverage efficiency (with the required Extra Board) is calculated as following: number of days when the actual absenteeism is smaller or equal to the daily absenteeism number previously determined, divided by 30 (*see annex S23, S24, N22 and N23 – COVERAGE EFFICIENCY row; for example, a coverage efficiency of 90% for the Southside Engineers on Mondays means that for 90% of the Mondays the actual absenteeism was fully covered by the extra board*). It is different to the coverage capacity which represents the percentage of absences effectively covered by the Extra Boards.

1. Southside's Extra Boards.

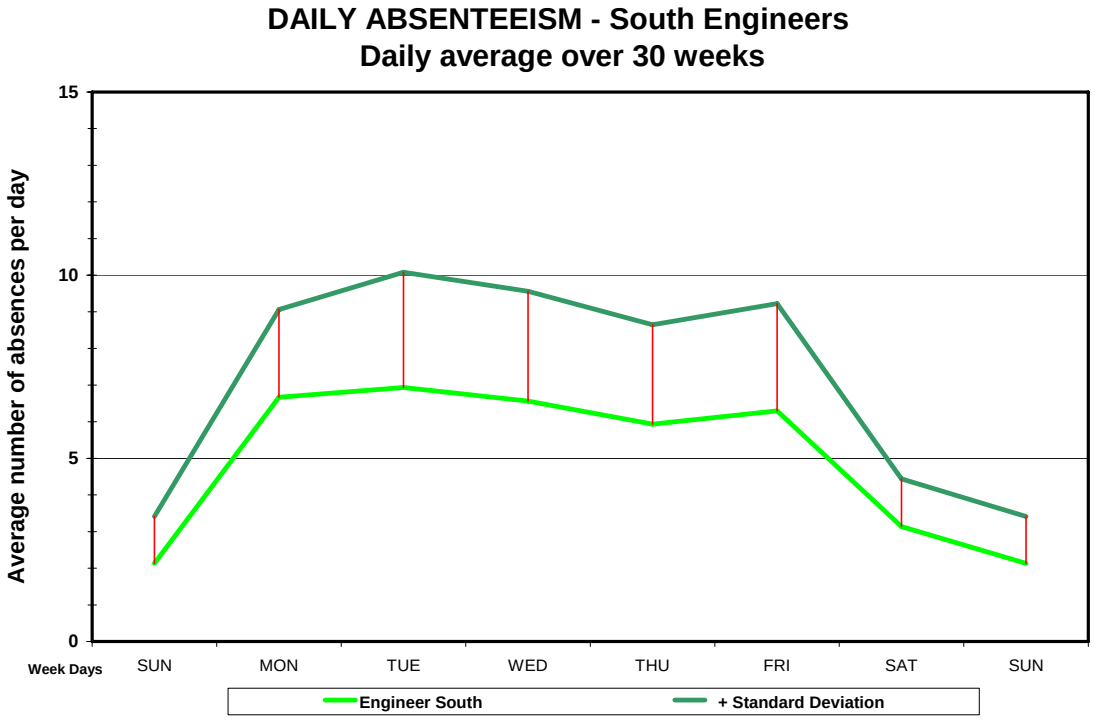

Figure 25: Southside engineers daily absenteeism's variation

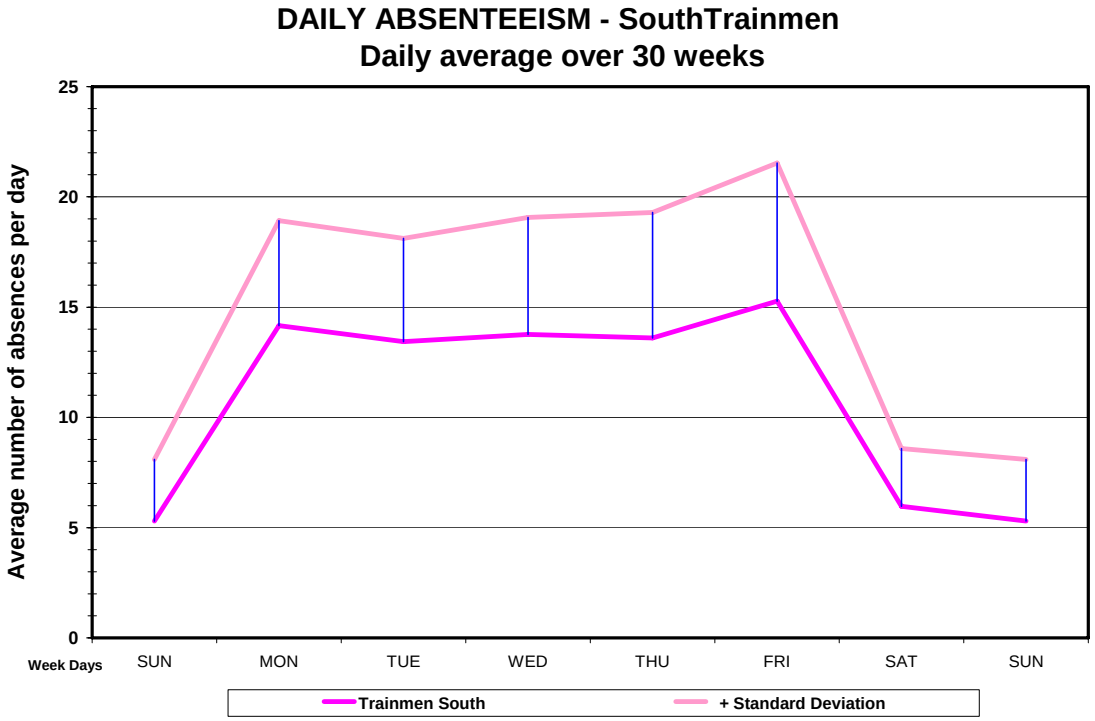

Figure 26: Southside trainmen daily absenteeism's variation

Figure 25 and 26 represent the weekly evolution of the Southside daily absenteeism calculated as described previously. The length of the vertical bars represents the value of the standard deviation for each day. It is interesting to notice that adding the standard deviation basically emphasizes the shape of the curve. Another interesting observation is the fact that Mondays and Fridays are no longer peaks of absenteeism for the engineers when we remove the vacation. The peak now effectively occurs on Tuesday. Regarding the trainmen, Friday is still the main peak of absenteeism, but Monday looks more like any other day, especially when we add the standard deviation which is 20% more important on Thursday for instance.

ENGINEERS SOUTH	Vacation	Absenteeism	Extra assignmt	Current Extra Board	Required Extra Board	Variation
Monday	6	9		9	15	-6
Tuesday	6	10		9	16	-7
Wednesday	6	9		9	15	-6
Thursday	6	8		8	14	-6
Friday	6	9		9	15	-6
Saturday	2	4	5	8	11	-3
Sunday	2	3	5	8	10	-2
Extra Board needs						**6**

Table 63: Soutshide engineers' Extra Board hiring estimation

From this table we can estimate the needs for the Southside engineers' Extra Board. It is calculated as the sum of the daily extra needs (e.g. the last column) divided by 6, as each extra board employee only has one relief day. We come to the conclusion that 6 more employees in the Extra Board would be a benefit for MBCR as it would allow a full coverage of the absenteeism 85% of the time (average of the daily coverage efficiency if the extra board is larger by 6 persons), for a global coverage capacity of 97% over the 30 weeks (average of the daily coverage capacity if the extra board is larger by 6 persons).

TRAINMEN SOUTH	Vacation	Absenteeism	Extra assignmt	Current Extra Board	Required Extra Board	Variation
Monday	11	19		19	30	-11
Tuesday	11	18		19	29	-10
Wednesday	11	19		18	30	-12
Thursday	11	19		19	30	-11
Friday	11	21		19	32	-13
Saturday	3	9	12	15	24	-9
Sunday	3	8	7	17	18	-1
Extra Board needs						**11**

Table 64: Soutshide traimen's Extra Board hiring estimation

From this table we can estimate that 4 more employees in the Conductors' Extra Board and 7 more employees for the AC's Extra Board would allow covering all the trainmen absenteeism 87% of the time, for a global coverage capacity of 98% over the 30 weeks.

2. Northside's Extra Boards.

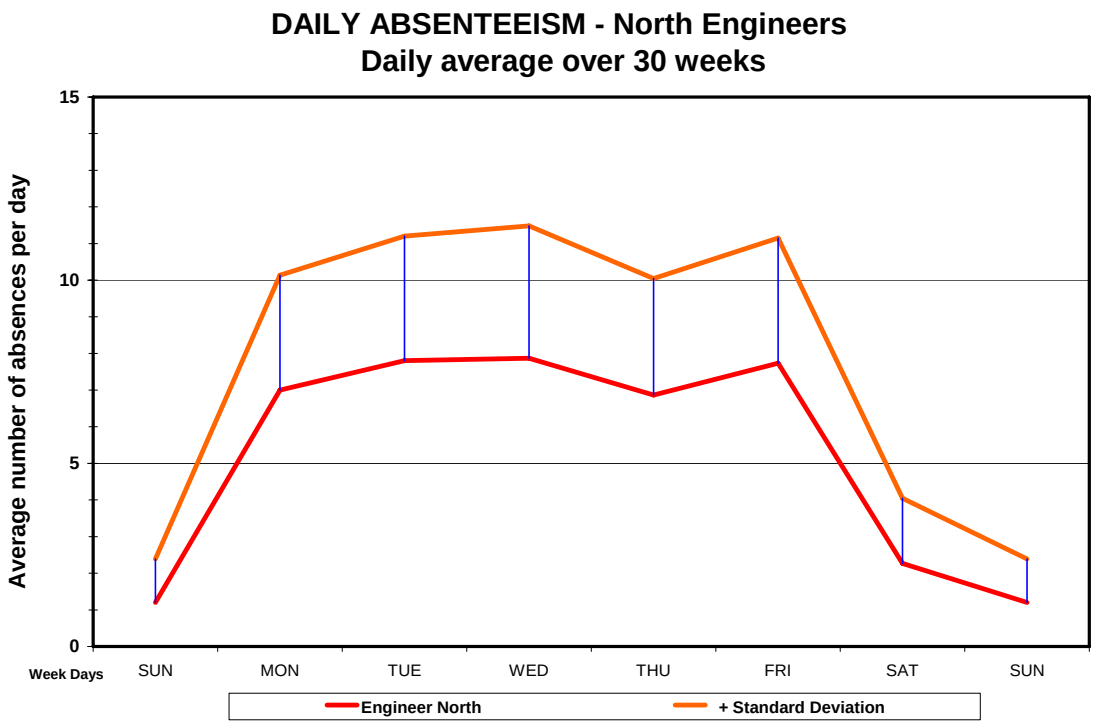

Figure 27: Northside engineers daily absenteeism's variation

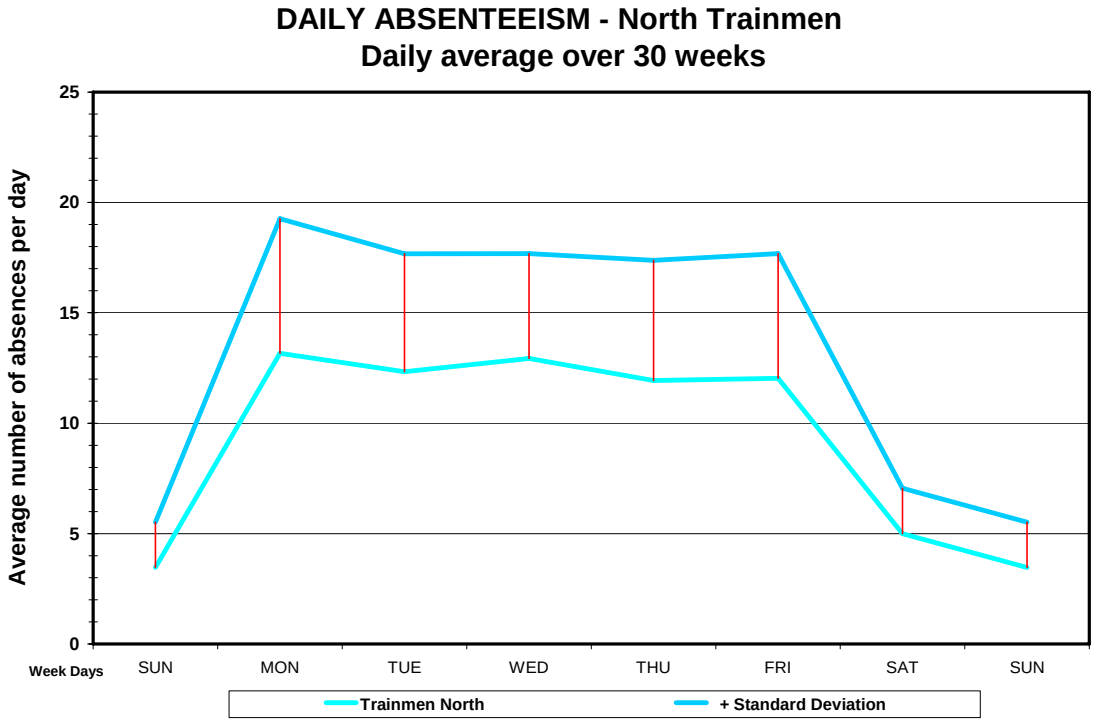

Figure 28: Northside trainmen daily absenteeism's variation

Regarding the Northside engineers, the curve is pretty similar to the Southside's one, with a minimum on Thursdays and a peak in the middle of the week (Wednesday in this case instead of Tuesdays on the South). We can notice that this shape is really close to the training curve (*see figure 12*), which can be easily explained as training is the main cause of absenteeism for this category. Regarding the trainmen, the peak occurs on Mondays, and then the absenteeism is quite stable all week long, especially if we look at the curve with the standard deviation added.

ENGINEERS NORTH	Vacation	Absenteeism	Extra assignments	Current Extra Board	Required Extra Board	Variation
Monday	4	10		8	14	-6
Tuesday	4	11		8	15	-7
Wednesday	4	11		8	15	-7
Thursday	4	10		8	14	-6
Friday	4	11		8	15	-7
Saturday	2	4	2	6	8	-2
Sunday	2	2	4	8	8	-
Extra Board needs						**6**

Table 65: Nortshide engineers' Extra Board hiring estimation

From this table we can estimate that 6 more employees in the Extra Board would be a benefit for MBCR as it would allow a full coverage of the absenteeism 87% of the time, for a global coverage capacity of 98% over the 30 weeks.

TRAINMEN NORTH	Vacation	Absenteeism	Extra assignments	Current Extra Board	Required Extra Board	Variation
Monday	6	19		16	25	-9
Tuesday	6	18		15	24	-9
Wednesday	6	18		15	24	-9
Thursday	6	17		15	23	-8
Friday	6	18		15	24	-9
Saturday	3	7		13	10	3
Sunday	2	6	5	13	13	-
Extra Board needs						**7**

Table 66: Nortshide trainmen's Extra Board hiring estimation

From this table we can estimate that 3 more employees in the Conductors' Extra Board and 4 more employees for the AC's Extra Board would allow covering all the trainmen absenteeism 84% of the time, for a global coverage capacity of 98% over the 30 weeks.

For both sides, the most efficient way to use the new extra board employees would be to determine their relief day based on the daily absenteeism evolution, so that the coverage can be maximized. Therefore the goal is to try to minimize the daily variation between the required number and the actual number.

II. Estimation of the required Extra Boards for the proposed network.

Assuming that the absenteeism remains the same, we can now determine the estimated number of extra employees to hire if the new runs and rosters detailed in the crew scheduling chapter become effective. On the tables below, the 2nd column "Number of employees required after proposal" takes into account the reduction of the extra assignments during the Week-end. Basically if six extra assignments are suppressed this corresponds to the need of one less employee for the extra board. The last column represents the number of employees that would need to be hired in order to have an efficient Extra Board, operating with the new rosters.

SOUTH SIDE	Number of employees currently required	Number of employees required after proposal	Number of employees provided by the proposal	Estimated number of employees to hire after proposal
Engineers South	6	5	0	**5**
Conductors South	4	3	0	**3**
AC's South	7	5	5	**0**

Table 67: Hiring estimation for the Southside proposed network

NORTH SIDE	Number of employees currently required	Number of employees required after proposal	Number of employees provided by the proposal	Estimated number of employees to hire after proposal
Engineers South	6	5	1	**4**
Conductors South	3	2	1	**1**
AC's South	4	4	2	**2**

Table 68: Hiring estimation for the Northside proposed network

Height new employees would need to be hired on the Southside and seven on the Northside to provide a full coverage of the absenteeism 85% of the time, for a global coverage capacity of almost 98% in average.

III. Impact of the new Extra Boards on the operation costs.

1. Cost forecasting for the current network.

The table 69 summarizes the impact on the costs of hiring new employees, for the current scenario. The last column gives the estimated weekly cost of the variation, calculated as five average pay days time the number of the variation.

EXTRA BOARD CURRENT ROSTERS	Current Extra Board	Required Extra Board	Variation	Extra Weekly Cost
Engineers South	10	16	+6	$ 10,650
Conductors South	9	13	+4	$ 5,880
AC's South	12	19	+7	$ 7,455
Total Southside			**+17**	**$ 23,985**
Engineers North	9	15	+6	$ 9,750
Conductors North	8	11	+3	$ 4,035
AC's North	9	13	+4	$ 4,280
Total Northside			**+13**	**$ 18,065**
Total Network			**+30**	**$ 42,050**

Table 69: Cost forecasting for the current network

Hiring 30 new employees for the Extra Boards according to the current needs would represent an investment of almost $2,200,000 a year, but the real cost for MBCR would actually be lower as the 6th and 7th days would be reduced by 90% in average (the average coverage capacity would jump from 77% currently to 98% with lager extra boards, which corresponds to a diminution of the uncovered absenteeism by 90%). That represents a saving of approximately $900,000 per year, so the real cost of improving the extra board coverage and therefore all the network operations would be around **$1,300,000** per year.

2. Cost forecasting for the proposed network.

This table is similar to the one above except that the figures concern the hypothetical case if the new rosters should be implemented. The proposal extra board therefore represents the extra board after the restructuring and the required extra board takes into account the reduction of the extra assignments. Finally the costs are estimated using the average pay day after the implementation.

EXTRA BOARD PROPOSAL ROSTERS	Proposal Extra Board	Required Extra Board	Variation	Extra Weekly Cost
Engineers South	10	15	+5	$ 8,500
Conductors South	9	12	+3	$ 4,230
AC's South	17	17	-	-
Total Southside			**+8**	**$ 12,730**
Engineers North	10	14	+4	$ 6,440
Conductors North	9	10	+1	$ 1,335
AC's North	11	13	+2	$ 1,980
Total Northside			**+7**	**$ 9,755**
Total Network			**+15**	**$ 22,485**

Table 70: Cost forecasting for the proposed network

If the new runs and rosters should be implemented, having the same absenteeism coverage efficiency than for the current case described above would require hiring 15 new employees for the Extra Boards. This would represent an investment of almost **$1,170,000** a year. However, we must not forget that the annual savings resulting from the implementation of the new rosters are estimated at $2,250,000. Moreover, those savings do not take into account the reduction of the 6th and 7th days for the Southside engineers and conductors. In fact, the Extra Boards of the Southside Road Crew were not modified by the restructuring. This means we can expect some extra savings, linked to the reduction of their 6th and 7th by 90%, estimated at $330,000 a year.

Therefore, we can come to the conclusion that the implementation of the new rosters plus the hiring of 15 new employees for the extra board could eventually lead MBCR to save more than **$1,400,000** per year on the whole network while considerably improving the efficiency of the operations at the same time. Speaking of potential savings' repartition, MBCR would save an estimated $1,100,000 a year on the Southside's operations and an estimated $300,000 a year on the Northside's operations.

PART 5: LIMITS OF THE RESULTS & FURTHER WORK

I. Interesting results but...

At the end of those studies, we have reached pretty interesting results, both for the crew scheduling project and for the absenteeism/Extra Board analysis. However, we must not forget that all those results have some limits in terms of efficiency and accuracy, especially when it concerns the costs' forecasting.

First of all, regarding the crew scheduling project, we have to keep in mind that the work described in this report is just a proposal, and that the negotiations with the unions haven't started yet. Some runs and/or rosters may possibly have to be readjusted to reflect comments received, and every modification will likely have a negative impact on the potential savings. Also even though the results of the crew scheduling project seem good, they may not be the most efficient ones. In fact all the runs and rosters were built by hand and mind, so the utilization of a crew scheduling optimization software can obviously lead to better results.

Regarding the rosters' costs estimations, some assumptions were used (seniority, extra assignments) that could lead to small errors on the final results. Moreover, all the costs calculations involving the Extra Board were performed with a singular method using mainly averages. Therefore we can easily understand that the actual costs may vary from what we found here, however it is difficult to estimate the accuracy of the forecasting capability of this method.

Finally, it will be interesting in the future to confirm or not the results obtained in the absenteeism analysis by studying a longer period of time which would include the months of July and August. We might actually experience some noticeable differences that could have an impact on the extra board's estimation.

II. The further work related to the optimization of the passenger crew utilization.

The next months will be the opportunity to perform the following steps that would allow going deeper into the global problematic of optimization of the passenger crew utilization:

- Negotiations with the Unions;
- Possibly reworking some runs and rosters to reflect comments received;
- Possibly working on the actual implementation of new schedules;
- Diagram Compendium for MBCR: standardization of all the moves and process based on a set of documents used by CONNEX in the UK;
- Working on the process and the work organization;
- Working on the feasibility of 8 hours runs (assuming a proper growth of the human resources);
- Testing and evaluating the possibility of the implementation of a crew scheduling software, among HASTUS, OPCOM and AUSTRICS;
- Possibly implementing one of those softwares as part of the crew management process.

CONCLUSION

This report dedicated to the optimization of the passenger crew utilization for MBCR clearly highlights the importance of the crew management in the Railroad Transportation. In fact an effective utilization of the available human resources greatly improves a railroad transit operation's reactivity and service quality, minimize the overall roster costs, and can improve both customers' and employees' satisfaction.

Crew scheduling and crew rostering are two of the major tasks involved in managing large transportation networks and are concerned with the development of duty schedules for crew to cover a given timetable in a transportation system. At the end of this crew scheduling project for MBCR, we clearly demonstrated that the implementation of new runs and rosters for the passenger crew could lead to significant potential savings. In fact, if the proposed scheduling should be implemented, the passenger operations' costs would go down by more than **$2,200,000** per year.

Approximately one half of those potential savings would be linked to the restructuring of the Road Crew runs and rosters, and mainly come from the improvement of the crews' productivity and the reduction of the overtime. The other half is the consequence of the restructuring for the Assistant Conductors' scheduling, and essentially results from the reduction of the overstaffing and also the improvement of the productivity. In terms of network's repartition, the passenger operations' costs would go down by more than **$1,400,000** on the Southside and by almost **$800,000** on the Northside.

Using the 2003 CONNEX RFP Crew Runs as a starting point, the new crew schedules were built with a management approach that would create the opportunity to provide the existing service with fewer resources. The difference between the resources currently used and the workforce required after proposal benefit to the Extra Boards. As a consequence of the Extra Boards' growth, the costs of the 6^{th} and 7^{th} days are going down, while the absenteeism coverage efficiency is improved.

The last part of this report which combines the results of the absenteeism analysis and the vacation analysis highlights the fact that the Extra Boards are currently too short to absorb all the daily absenteeism. In fact, we demonstrated that an optimized coverage of the absenteeism would currently require hiring 30 new employees. This represents an estimated investment of almost $2,200,000 a year, which would be lowered by approximately $900,000 due to the reduction of the 6^{th} and 7^{th} days. The same study performed for the proposed network with the new runs and rosters leads to the conclusion that 15 new employees should be hired to provide the same efficient coverage of the absenteeism. Deducing the cost of this investment to the potential savings resulting from the new schedules, we came to the conclusion that MBCR could save almost **$1,400,000** per year on the whole network while considerably improving the efficiency of the operations at the same time.

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